WATER & SEWAGE WORKS

REFERENCE *and* DATA NUMBER

JUNE 30, 1957

Water & Sewage Works Presents Its 1957-58 R & D Number

This is 24th annual
reference and data section of
Water & Sewage Works.

The 1957-58 Number
is issued with the continued
intent of the publisher and the editors
to produce a useful reference and information work.

Each Reference and Data Number
is a handbook divided into ten sections which cover management, maintenance, operation, and engineering fundamentals in the field of water and sewage works practices. Each year, the "handbook" is revised and updated with new articles and reference material published during the preceding year.

Fundamental Articles
of lasting interest and usefulness are reprinted
in the Reference and Data Numbers at intervals of two
to three years. This practice is followed to provide new
subscribers with basic material for their libraries.
It is suggested, therefore, that subscribers retain the last
three Reference and Data Numbers in order to have a
complete reference work on the subject of water and sewage works.

All subscribers
to Water & Sewage Works receive the Reference and
Data Numbers without extra charge.

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I. INTRODUCTION

THERE ARE a number of valid reasons for covering the subject of water and sewage works practices in the same volume. That this is true is evidenced by the increasing trend of municipalities to place the management of both water and sewage facilities in one department or under one man. Latest figures developed from a survey of all the states shows that an average of nearly 65 per cent of the communities follow this practice.

Among the factors common to both water and sewage are hydraulics, physical and chemical treatment problems, and colloidal properties of water. Sewage is the used water supply of a community and the management of both are municipal functions, except in a few instances.

Because of this "oneness' of water and sewage treatment, it is both possible and desirable to adopt the format and outline used in this reference work.

In the management of both water and sewage facilities, there are similar problems of financing, office management, public relations, policy and safety.

Functional Operations

In this reference text, the following subjects are treated as common to both water and sewage and are therefore considered as functional operations: Pumping, electricity, flow measurement, instrumentation and control, chemical handling and feeding, coagulation, sedimentation, corrosion control, laboratory control and maintenance.

There are any other phases of water and sewage works practices that have elements of similarity and oneness. For example, water works have distribution systems while sewage works have collection systems. Treatment of water and sewage often involves the same approach, as for example in chlorination. The detailed operations of water and sewage works, however, often have enough different factors involved that it appears desirable to treat these details separately. This is done in this text to the extent necessary for best use of this reference work.

Water Works Operations

All water supply problems begin with the source of supply and source of supply involves the hydrologic cycle including evaporation, precipitation, transpiration, runoff and, of course, storage both on the surface and in ground water aquifers.

Distribution of water supplies includes not only the network of pipes throughout a community but also elevated storage, valves, hydrants, house services, metering and such operation problems as main laying and cleaning, loss of carrying capacity, pressure, etc.

The treatment of water will depend on its source (ground or surface) and its chemical content. Surface supplies usually will require sedimentation and chlorination as a minimum. If the surface water supply is turbid or colored, coagulation and filtration may also be required; and if tastes and odors are present, their removal is desirable. Surface waters may also be subject to softening and iron and manganese removal. Ground waters may be hard and thus require softening; they usually do not require filtration or coagulation and sedimentation unless iron and manganese removal is necessary. Tastes and odors seldom occur in ground waters. Miscellaneous water works operations include fluoridation among others.

Sewage Works Operations

While water work operations have problems of sources of supply, sewage works have a similar problem of effect of the waste on the receiving body of water. Stream pollution is important, therefore, particularly if the treated sewage reaches a body of water which serves as a water supply source.

Sewage treatment involves four basic processes: primary treatment, secondary treatment, disinfection, and solids disposal. Primary treatment deals with the removal by mechanical or physical means of suspended matter in the sewage. Secondary treatment is a biological oxidation (or wet burning) process for the stabilization of dissolved and colloidal organic matter. Disinfection is employed to destroy disease producing and harmful bacteria.

The disposal of solids is a highly important factor in sewage treatment. Methods of disposal may consist of digestion and dewatering followed by drying or incineration. Drying may be on open beds or in furnaces. Ultimate disposal of the final solids left after treatment may involve filling low areas, barging to sea, or use as a soil conditioner depending on the treatment. All of these approaches to the problem are dealt with in this book.

Industrial Wastes

Today the subject of industrial wastes has become so broad and so important that it is a field of its own although still allied to water and sewage treatment. The problem of industrial wastes is particularly important to municipal sewage treatment when these wastes are discharged to city sewers for treatment with the municipal sewage. How to treat such wastes and how to charge industry for such treatment is quite important to municipalities.

Design and Construction

Almost without exception, every municipality has an interest in the problem of design and construction of both water and sewage facilities. Without doubt, the proper design of facilities must take into consideration the problems of operation, maintenance and safety.

Construction likewise is important to municipal officials and superintendents of both water and sewage works. Whether or not to own or rent equipment for laying mains or sewers or to hire the work done by contract is a decision important to the efficient operation of these works. For that reason current articles of basic import to this subject are included in the Reference & Data Numbers.

Engineering Fundamentals

Among the engineering fundamentals of importance to both water and sewage works are chemistry and bacteriology, hydraulics and mathematics. For this reason these "handbooks" published as an extra number of *Water & Sewage Works* include articles, diagrams, tables, and data of a basic importance to this field.

Bulletins and Catalogs

There is one thing that every person needs in the field of water supply and sewage disposal. That is information on where to find equipment and services that will perform a job or function desired. Such information is, of course, contained in the bulletins and catalogs which equipment manufacturers issue.

In order to inform the reader of where he can obtain this information, as well as what is available, these Reference & Data Numbers include a section which contains brief summaries of such bulletins and catalogs.

For the aid of the reader a card is included by which he can easily request any number of these bulletins or catalogs. In this manner it is intended to increase the usefulness of this Reference & Data Number of *Water & Sewage Works.*

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ONE HUNDRED
BEST Water and Sewage BOOKS

For Engineers, Chemists, and Plant Operators

Compiled by
HARRY A. FABER

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U. S. Public Health Services, Washington, D. C.

This is a practical list of reference books for the water and sewage field. It is based entirely upon the recommendations of engineers, chemists, and plant operators who use these books.

The list was compiled by means of a questionnaire which asked only "Will you provide a list of those water and sewage books which you find most useful?" More than seventy replies were received, well distributed over the United States and Canada. These represent a good cross-section of water and sewage interests: design, operation, and control. They also represent a wide range of selections: from a few books recommended by the operator of a small treatment plant, to a large number recommended by the director of a State laboratory.

One hundred books receiving the highest number of recommendations were selected as the basis of the list. These were arranged in six classifications, and in each classification the book most frequently recommended was placed highest.

Many of the replies recommended the AWWA and FSIWA *Journals* as most useful "books." Frequent mention was made of the R & D issue of this magazine, and also of the monthly issues of several technical magazines which serve the water and sewage field.

It should be recognized that this list may not give a high recommendation to recently published water and sewage books, or may not list them at all. With the passage of time, newer books will certainly find their place in a list of 100 best water and sewage books.

Thanks are due to each engineer, chemist, and plant operator who contributed the time to prepare his personal list.

General Water and Sewage

Water Quality and Treatment. AWWA Manual.
Am. Wat. Wks. Assn., 2nd Ed., 1950.

Modern Sewage Disposal. Anniversary Book.
Fed. Sew. & Ind. Wastes Assn., 1938.

Stream Sanitation. E. B. Phelps.
John Wiley & Sons, Inc., 1947.

Public Health Engineering, Vol. 1. E. B. Phelps.
John Wiley & Sons, Inc., 1948.

Public Health Engineering, Vol. 2. E. B. Phelps.
John Wiley & Sons, Inc., 1950.

The Quest for Pure Water. M. N. Baker.
Am. Wat. Wks. Assn., 1948.

The Conservation of Ground Water. H. E. Thomas.
McGraw-Hill Book Co., 1951.

Engineering in Public Health. H. E. Babbitt.
McGraw-Hill Book Co., 1952.

Water Quality Criteria. Pub. No. 3.
Calif. State Wat. Poll. Cont. Bd., 1952.

Water, Miracle of Nature. T. King.
The Macmillan Co., 1953.

Principles of Sanitary Sciences and Public Health, Sedgwick's. S. Prescott and M. P. Horwood.
The Macmillan Co., 1936.

The Practice of Sanitation. E. S. Hopkins and A. P. Schulze.
Williams & Wilkins Co., 1954.

Stream Flow. N. C. Grover and A. W. Harrington.
John Wiley & Sons, Inc., 1943.

Chlorine Manual.
The Chlorine Institute, Inc., 2nd Ed. 1954.

Lime Handling, Application and Storage in Treatment Processes. W. Rudolfs.
National Lime Assn., 1949.

Glossary-Water and Sewage Control Engineering.
Joint Committee. ASCE, APHA, AWWA, FSIWA, 1949.

Fluoridation as a Public Health Measure. J. H. Shaw.
Am. Assn. for Adv. of Science, 1954.

Industrial Utility of Public Water Supplies in the U. S., 1952, E. W. Lohr and S. K. Love
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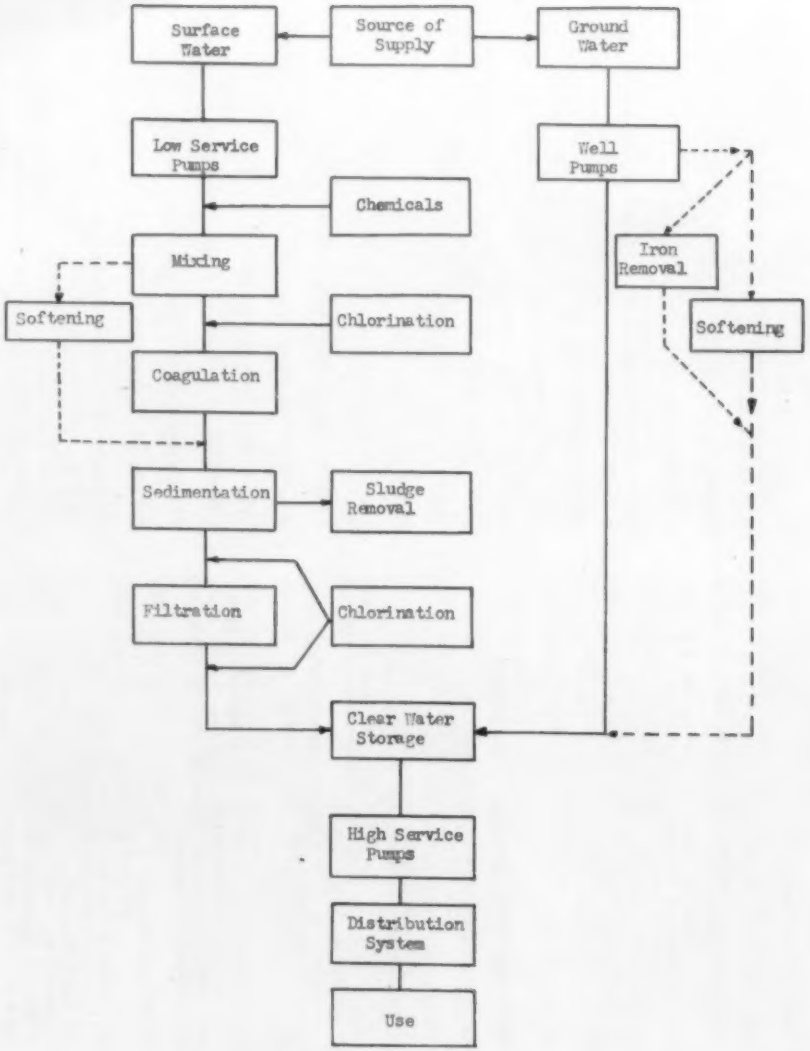
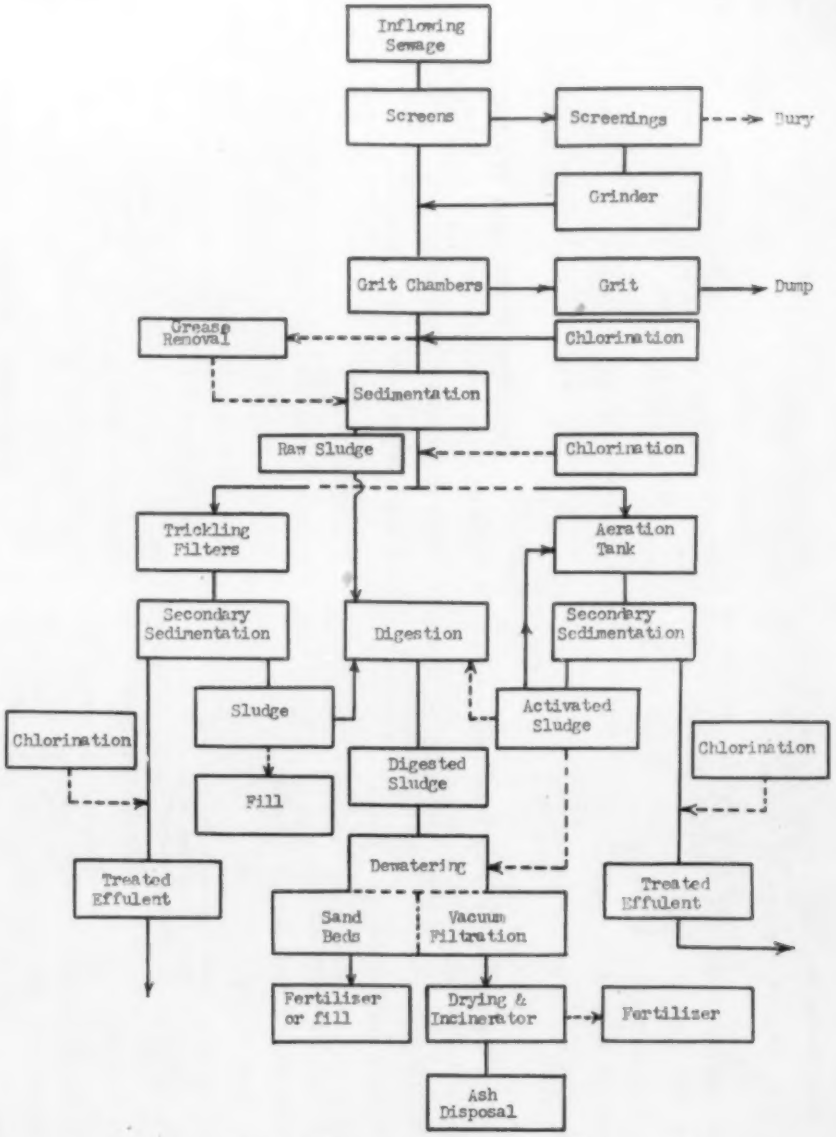


FLOW diagram of water supply system



FLOW diagram of sewage treatment works

II. MANAGEMENT

NO WATER or sewage works builds and operates itself, no matter how large or small or how automatic. This means that there must be property, financing, and contact with the public. It means that there must be operating personnel, supervision and safety. In short, it means that every water or sewage works must meet the problems of management. This section is devoted to the subject of management and the problems it entails: Financing, rate structures, office operations, public relations and policies, lands, legal decisions, and safety.

Financing

Water utilities may be private, public, or industrial. Sewage works are usually municipally owned. It doesn't matter! All water and sewage utilities must be provided with finances for both capital expenditures and operations. The particular financing program utilized depends on many factors, as indicated in this outline.

I. Capital Expenditure Financing-General
   - A. Municipal Owned Water Utility
     1. General Obligation Bonds
     2. Revenue Bonds
     3. Special Tax Assessments
     4. Surplus from Operation Revenues
   - B. Privately Owned Utility
     1. Bonds
     2. Stocks
     3. Surplus from Operating Revenues
   - C. Sewage Treatment Works
     1. General Obligation Bonds
     2. Sewer Revenue Bonds
     3. Sanitary District Bonds

II. Capital Expenditures—Specific
   - A. Extensions (Water or Sewer)
     1. Special Assessments
     2. Contracts with real estate developers
     3. Surplus
   - B. Metering Programs
     1. Bonds
     2. Special Assessments
     3. Surplus

III. Operation Financing
   - A. Municipal Water Utility
     1. Charge for service
     2. Tax funds
   - B. Private Water Utility
     1. Charge for service
   - C. Sewage Works
     1. Sewage service charge
     2. Tax funds
     3. Sanitary district tax levy

Rate Schedules

There is no rate schedule problem in communities where funds for water and sewage works operations are provided out of tax levies. In other communities charges for water and/or sewage service are based, in varying degrees, on benefits received. Basically any rate for either water or sewage service must provide monies for:

1. Operating Costs: Personnel, overhead, power, supplies, maintenance, insurance.
2. Amortization of bonded indebtedness.
3. Surplus and Contingency.

From simple to complex, the various rate structures for water are: (1) Flat rate per service per unit time; (2) Rate based on number of plumbing fixtures; (3) Rate based on measured volume of water used; (4) Sliding scale rate based on water used with standby or ready to serve charge plus special charges for fire service, etc.; (5) Combination tax and sliding scale meter rate.

The simplest sewage service charge is a flat rate based on some unit of time, or of consumption, or of production in the case of industry. The simplest rate based on water consumption is some percentage of the water bill. In the case of industry more complex rates are based on quality as well as quantity of the waste; still more complicated rates are based on tax levy, water consumption and waste concentration.

Office Operations

A water or sewage works cannot operate and serve the public without an office of some sort, and every office will find it necessary to maintain records of property, operation, service and finances. The number and type of records, and degree of detail will depend on the kind of water or sewage works, its size, number of people served, type of rate structure, treatment involved and other factors.

In a water works, records are kept of distribution systems, meter installations, valves, locations, personnel, operating expenses, income, complaints and service, volume pumped, non-revenue water, treatment operations, etc. In sewage works, records are kept of sewers, manholes, overflows, volume, treatment, income, expenses, personnel.

The record forms should be designed to meet the needs of the utility. State boards of health often prescribe the general form of treatment plant records. Standard business forms may be utilized in business operations or may be specially designed to fit specific business record machines. Engineering records, meter records, etc., usually fit the personal preference of the management. In large water systems, automatic business machines and record systems aid operations as does radio dispatching of service crews.

Public Relations

In the words of the Amer. Wat. Wks. Assn., "Silent Service is Not Enough." Every water and sewage works supervisor and operation should make an effort to develop and improve good relations with the public being served. At the same time efforts should be made to keep the public conscious of the service it receives. The establishment of sound operation and service policies is an essential part of good public relations. The technical associations (AWWA and FSIWA) both foster the development of public relations programs.

Lands and Laws

All water and sewage works must own some land and must have rights of way for distribution systems or sewer lines. Some large surfaces supplies own many acres of land as reservoir sites and this land must be protected and managed. In some instances the reservoir drainage area may be farm land which can be profitably farmed in one way or another.

With the owning of property, management will have legal problems. There are laws regulating commissions, utilities and their operations, rates, etc. Legal restrictions exist regarding stream pollution, delinquent accounts, cross connections, lines in highways, etc. There are few operations in water and sewage works management that do not in some way involve legal problems.

Safety

Until the late 1940's, little serious attention was given to safety programs in water and sewage works operations. As a result, the accident incidence and severity rate in water works was higher than in other industries. More recently, the AWWA has developed a program to interest water works men. The FSIWA is also keenly interested in the problem and many articles have appeared in the technical press on the subject.

Long Range Planning for Water Service*

Requires some revision in past thinking and a raising of sights, looking to realistic service.

by ABEL WOLMAN

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THE RECORD in the United States for providing people with water service is one of which any citizen might be justly proud. Perhaps in no other country in the world has public water supply been so universally afforded at such low cost as in this country. Why then should one still concern himself with the subject of long range planning for water services.

The history of water service demonstrates that the problems of planning have long confronted the professional practitioner. Emphasis on such planning is not new. The literature in the water works field is filled with careful technical consideration of the complex problems of providing water.

In the last two decades the nature of such planning, however, has in some respects been modified. The long look at the water issues which now concern the professional worker discloses a somewhat different and broader aspect. One of the major characteristics of water supply service in the past has, with some important exceptions, been that it has been confined largely to the development and extension of water service within limited political boundaries, usually those of the familiar municipality. These problems within such circumscribed areas have been resolved over the years with skill and with economy. Where the solutions have fallen behind in actual execution, the causes have been essentially of political, administrative and fiscal natures.

*A paper presented before the Pennsylvania Water Works Ass'n. It was published in *Water and Sewage Works* by authorization of the Association.

A New Set of Issues to be Dealt With

Today, however, we are confronted with a new set of issues, which represent the subject matter of this paper. The changes which create new or intensify old problems are those which we generally ascribe to metropolitan areas. The phenomena associated with the growth of the metropolitan areas are of relatively recent origin. They confront the developer of water service with issues broader in scope, wider in geographical coverage and more amorphous than previously. The metropolitan areas likewise represent a nationwide, rather than a local or regional, development. It is within this particular setting that the long range planning of water service is here discussed.

And, New Areas for Service

In 1956 approximately 172 metropolitan areas of well defined characteristics exist in continental United States. Some 42 states and the District of Columbia are represented by such areas. Only the states of Idaho, Montana, Nevada, North Dakota, Vermont and Wyoming do not contain at least some areas within the current Census Bureau definition.

More than half of the nation's population now lives in metropolitan areas. Something approaching 90,000,000 people are thus accounted for.

Not all of these areas, of course, are enormous in size, although there are 33 of these which have populations in excess of 500,000. The areas apparently are growing in acreage and in population and will undoubtedly by 1960 account for over 100,000,000 people.

The significance of these figures lies in the fact that the country was generally unprepared to meet the utility requirements of such areas which spilled beyond the political units normally geared to meet such requirements. The unfortunate results of this lack of preparedness, not only in technology, but in administrative structure and finance, are a familiar story.

Efforts to meet these growing problems, in relatively unfamiliar settings, have ranged all the way from the successful devices used for years in the Boston Metropolitan District and in the Washington Suburban Sanitary District to completely chaotic and "hand-to-mouth" operations in most other metropolitan areas. In these latter cases, the situation has successfully escaped the impact of careful advance thinking. As a result, the next quarter of a century will obviously show the necessity for major reconstruction, considerable duplication in expenditures or increasingly limited water service.

Both private and public workers in this field have defaulted in visualizing realistically the nature of the problem or have been slow in activating new solutions. The orthodox water planning, geared to restricted geographical areas and to the considerations of earlier decades, has inhibited more imaginative solutions. The traditional political boundary has perhaps played an unfortunate part in restraining water service, whether publicly or privately owned, even though at the same time it has provided many skillful technological aids. An awareness of these realities is a

pre-requisite to solving problems which new and unexpected demands have posed.

Guiding Principles

It is not the purpose of this paper to present a check list of the items to be kept in mind in planning for water service. Such check lists have been authoritatively presented in the professional journals. Little needs to be added to them, since they afford excellent and detailed guide lines for the interested worker.

The most useful contribution would be to discuss those guiding principles which must be militantly confronted, if we are to recover and to guarantee adequate water service in the metropolitan areas. These principles may be assumed to cover some five major areas, as follows:

(a) Technology
(b) Administrative Structure and Management
(c) Finance
(d) Research
(e) Legislation

(a)—Technology.

Although it may be stated with some assurance that the technological prospect of providing water service in metropolitan areas is the most optimistic, one should not lose sight of the fact that even in this particular function much remains to be done to diagnose and to expand the quality of water service. Perhaps one of the most critical features in this field is the rising evidence that the water works practitioner has too often neglected the complex problems of distribution. The present emphasis on distribution diagnosis and design has its root in the same traditional adherence to more densely populated areas already referred to. If people had not elected in the last two decades to move in increasing numbers to broader and less dense areas and to properties with more lawn space, the orthodox water distribution design would have served without serious defects.

These suburban shifts in demand are the subject of a wide variety of diagnostic studies in many parts of the United States. They represent a growing recognition of the fact that the changing demands for water force a prompt and new evaluation as to how best to distribute it. The situation obviously will not be met by bemoaning privately the extraordinary habits of the American people and by resisting to the last ditch their insistence to be allowed the use of water for purposes which they prefer and in amounts which they desire.

The prime necessity in technology is an immediate evaluation of these requirements. At the same time the translation of these requirements into actual availability has always taken too long. The author recently reviewed the steps required to complete the construction of the Savage River Dam in the State of Maryland. The dam was designed to increase the low flow of the Potomac River for water supply and stream pollution abatement requirements. The proposal for this project was initiated prior to 1931. Its development wandered through decades of fits and starts, several wars, a depression, minor financial emergencies, international diplomatic battles, controls of materials and labor, and repeated efforts for the raising of additional moneys.

In 1951, more than 20 years after the initiation of the idea, the dam was finished and ready for operation, with water actually being released to afford the benefits originally contemplated.

The experience of New York City in the development of its additional water sources over the last quarter of the century is a further demonstration of the long time lag which has plagued the water works industry throughout its history.

These delays, of course, were not due to technological deficiencies, but to man-made obstacles, aided and abetted by the snail-like processes which control most public practice throughout our history. It is unfortunate that many people now adopt the fatalistic attitude that nothing can be done to speed up the processes in water utility service in this country. The time lag cannot be accepted for the forthcoming decades, since the problems are at our doors for immediate rather than for deferred decision and action.

In this respect, the technological issues and solutions may be used as the tools for speed rather than as the bases for delay.

(b)—Administrative Structure and Management.

Much too little consideration is still being given to the development of administrative devices designed to provide answers to the problem now confronting us. For the most part we still struggle with rural county administration to solve essentially urban utility problems. By and large, we still view the core municipality as the primary agent to restrict water service to surrounding areas. We still tacitly insist that the satellite areas design and install the water utilities on the most niggardly basis in order to keep within the philosophical scope of the revenue bond. Almost without exception these practices result in inadequacies of system and of service, in the piling up of problems for the future and in intensifying the general feud between the subdivider, the house owner, the county government and the water utility.

Opportunities for the consolidation of service are great. Obstacles to such accomplishments are equally great. They stand, however, as challenges rather than as reasons for no action.

There are, of course, excellent examples of intelligent long range approaches to satisfactory administrative practice. Some of these antedate by years the nature of the problems here described. One should remember that some of the sanitary districts and authorities, operating successfully for decades, were created in the period from 1915 to 1925. They are monuments to the imagination, vision and the long range planning instincts of distinguished engineers, administrators and political statesmen.

In view of their existence, as well as of their success, it is disconcerting that the lessons to be learned from them have not been more widely applied.

The most perfect diagnosis and design of a water utility in an expanding area is in a way fruitless, unless there also be an equivalent diligence in translating such a proposed system into an actuality by the creation of the agencies (if need be) which could accomplish such purposes.

(c)—Finance.

One of the major blocks to the provision of adequate service in most metropolitan areas is in the field of finance. Here again, the principles guiding us in the past, with some exceptions, are not adapted to the requirements of the present and the future. In order to circumvent the problems of tax limitations, the last few decades have been characterized by the ascendency of the revenue bond as the savior of the water works industry. However, that it alone cannot save the industry should be apparent to any careful investigator of the metropolitan problem.

The revenue bond rests upon the assumption that the user of water is naturally the sole base of payment for the system. This fundamental principle is more apparently valid than it is in reality. It was probably close to the truth when the new consumer represented a small and leisurely addition to the total body of consumers, when the system was compact in nature and in coverage, when the area was either static or

slow in expansion and when the design could keep reasonable pace with the growing requirements of a compact community. Most of these characteristics are inapplicable to the metropolitan areas as we now know them.

Few are willing to acknowledge that the general ad valorem tax and the front foot assessment are essential ingredients of any rapidly expanding water economy. The pursuit of the revenue bond principle to its bitter end in many metropolitan areas has resulted in undersized systems, in inadequate operation, in the almost complete absence of long range plan and in the ultimate scrapping of a good many small systems independently financed. All of these untoward results stem from the fact that the present and future participants are unwilling to accept the axiom that a water distribution system is an integrated entity and not a series of independent units designed and constructed without regard to the ultimate form and balance of an integrated system.

What we see now are minimum sizes of mains for satellite communities, each clinging religiously to a revenue bond principle, wholly inadequate to finance the present or the prospective requirements of the area. The eye is focused on the immediate, whereas the true solution must provide for the next 40 to 50 years.

It is interesting to speculate how long it will be before we might all confess that the water utility of the future, within the areas here discussed, must rest upon the combined base of more than one of the following sources of money.

(1)—The ad valorem tax for the larger sized mains and plant additions required for adequate future service.

(2)—The front foot assessment for the individual house.

(3)—The water consumption payment by the actual user.

To place *all* the emphasis upon the third of these sources of revenue, in the kind of setting which now confronts some 100,000,000 people, is unrealistic if not already fatal. In addition, such a choice either results in a poor system, or loads the present consumer with burdens which in part belong to future consumers.

(d)—Research.

One cannot speak of long range planning for water service without a major emphasis upon the things which we do not know. The range of opportunities for research and development is great. It moves over the entire spectrum, from automation to detailed analysis of the impact of the behavior of people upon water use.

We have adhered too long to the assumption that our design should rest upon the fact that historically the ratio of the maximum day consumption to the average day should approximate 150 per cent. Man has a habit of deviating from the professional's rule.

The professional may elect to ignore man's demands or he may adjust his diagnoses and his solutions to the inevitable. The fantasy of planning for a water works expansion independent of and unrelated to the desires and habits of the public may be entertaining, but is certainly a fruitless effort.

Research should point the way to how the long range determination of water works needs may be used as a guide for the design and redesign of systems and for their adequate financing and management.

(e)—Legislation.

If any of the guiding principles so briefly noted above are to find full implementation, major adjustments in legislation will be required in most parts of the United States. It is not asking too much that the water works practitioner should devote an increasing amount of time to the determination of the kind of legislation so required. He must, in addition, actually prepare or participate in the preparation of such legislation. He must undertake to press for its passage, he must roam the halls of legislative assemblies to advise, to persuade and to coerce the development of such legislative sanctions.

It is not enough to bemoan the absence of such legislation or to point out that the engineer is not the logical or appropriate agent for the stimulation of such enactments.

Unless the engineer engages in such activities, the probability of crystallizing better practices and meeting the water demands of the future more promptly are exceedingly low.

The Long Range Objective

Water service of an adequate nature, at a reasonable price, is an attainable objective.

If this has not yet been attained, it is only because the skilled workers in this field have not seen fit to define the objective, to delineate the principles which should control its implementation, to devise the form of structure for administration and management and to establish the fiscal principles which might safely and wisely provide the sinews for the project.

All of these opportunities are at hand. Many of them have already been partly crystallized.

What is lacking is the enunciation of the guiding principles in detail, their acceptance in fact and their translation *militantly* into reality. Such a prospect is an exciting one.

If this paper has done nothing more than to press forward such undertakings, it will have accomplished its major purpose.

The Sewage Authority Approach To Stream Pollution Control *

by ROBERT S. SHAW

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NEW JERSEY municipalities and industries are spending a total of approximately $250 million in their current construction programs for sewage collection and treatment and industrial waste treatment. The word "current" is used in this instance to describe construction which has been completed within the last two years or which, in all probability, will be completed within the next three years. Sewerage authorities, relatively new instruments of government, are responsible for more than 50 per cent of the current construction program in New Jersey.

The current construction program has reached its high level despite the fact that already there are more than 400 treatment plants, including more than 100 industrial waste treatment plants, in the State. The impetus for the program is derived from 4 principal facets of the stream pollution control problem in New Jersey.

Reasons for Program

First, it is significant that more than 30 per cent of the sewage treatment plants in New Jersey were constructed prior to 1920. More than 50 per cent of the sewage treatment plants are more than 25 years old. Also, more than 50 per cent of the industrial waste treatment plants are more than 15 years old. These statistics show that in the period following World War II New Jersey found itself with a large number of overloaded and antiquated sewage and industrial waste treatment plants.

A second significant facet of the problem is population density of New Jersey, which is second only to that of Rhode Island. This condition has obliged the State Department of Health to require more intensified sewage treatment methods in locations where lesser degrees of treatment formerly were considered adequate.

A third significant facet, at least in terms of treatment plant numbers, has been the widespread adoption of small "package" treatment plants and miniature conventional plants to serve realty subdivisions, in and beyond the fringe areas. It has become a trend in the larger subdivisions in New Jersey to construct sanitary sewers and sewage treatment plants in preference to individual home sewage disposal facilities.

A fourth facet of the problem, and a phase of tremendous significance, has been the construction of treatment plants to discharge into interstate waters. This phase of the program derived impetus from the Interstate Commission on the Delaware River Basin, better known as Incodel, and from the Interstate Sanitation Commission operating in the New York City metropolitan area. Little progress was possible and little was accomplished in these interstate areas until Incodel and the Interstate Sanitation Commission were established.

Sewerage Authority Authorization

In order to provide a concept of how sewerage authorities have fitted into the stream pollution control problem in New Jersey, a brief review of highlights of the general sewerage authorities law of the State is necessary. It should be made clear that the term "sewerage authority" does not encompass such organizations as the Passaic Valley Sewerage Commissions, or the many joint meetings which are operating in the sewerage field in New Jersey. The latter agencies were predecessors to sewerage authorities in this State. They were, within limits, endeavors of government to accomplish some of the purposes of sewerage authorities.

The general sewerage authorities law in New Jersey is known as Chapter 138 of the Laws of 1946. It was enacted to extend and implement the State policy established in 1899 toward relief of waters of New Jersey from pollution. The law seeks to accomplish its purposes by authorizing the creation of sewerage authorities empowered to provide sewerage services at the expense of users without increasing the burden of general taxation.

A sewerage authority is an agency of government representing one municipality or a part thereof, two or more contiguous municipalities, a county or a part thereof. Sewerage authorities are created by local, county or municipal government. When more than one municipality is involved, an authority is created by the concurrent action of the interested municipalities, or by the action of county government. Once created, sewerage authorities are empowered to operate as independent agencies of government.

In the language of the law a sewerage authority is a "public body politic and corporate" constituting a political subdivision of the State, established as an instrumentality exercising public and essential governmental functions to provide for the public health and welfare. An authority may sue and be sued. An authority may acquire. hold and use, and dispose of service charges or other revenues. It may acquire by purchase, gift, condemnation or otherwise real property and easements necessary or useful for its purposes. It may provide for and secure the payment of any bonds and the rights of the holders thereof. It may enter into contracts for the purposes of the authority.

Financial Details

A sewerage authority is authorized to charge and collect rents, rates, fees or other charges usually referred to as service charges. The law establishes limitations within which an authority must work in establishing rate schedules. The law requires that service charges be as nearly uniform as practicable throughout the district served for the same type and amount of service. The law also establishes various means for setting up rate schedules.

The most significant provision of the law in relation to charges is the requirement that the revenues of a sewerage authority will at all times be adequate to pay all expenses of operation and maintenance of the sew-

* Reprinted from *Sew. and Ind. Wastes*, Vol. 28, No. 2, p. 195 (1956)

age system including reserves, insurance, extensions and replacements; to pay punctually the principal and interest on any bonds; and to maintain such reserves or sinking funds therefor as may be required by the terms of any contract of the sewerage authority, or as may be deemed necessary or desirable by the sewerage authority. The law also makes provision for the revision of service charges from time to time as deemed necessary.

It is important to note that the bonds issued by a sewerage authority do not constitute in any way a debt or liability of the State or any unit of local government. Sewerage authorities are not permitted to incur any indebtedness on behalf of the State or any county or municipality.

Powers of an Authority

After a sewerage authority has been created, no sewage disposal plant or other facilities for the collection, treatment or disposal of sewage arising within the district of the authority may be constructed without the approval of the authority. Sewerage authorities also are granted police powers over stream pollution within their district. They share these powers with the State Department of Health.

The foregoing brief summary of the provisions of the sewerage authority law omits many technical details required to establish a sewerage authority. Perhaps the most significant conclusions to be drawn from this summary are that sewerage authorities are agencies of government, and that they represent delegation of authority by local, county or municipal government in the sewerage field.

Political Considerations

The sewerage authorities law was borne of economic and political expediency. The local tax burden had become great, and legal debt limits had been approached or exceeded in many municipalities; thus it was deemed advisable by fiscal authorities that some means should be provided for establishing, operating and maintaining sewerage facilities on a fiscal basis independent of other local government services.

Obviously there also were political implications involved. During the late 1930's and early 1940's the State Department of Health in New Jersey was very active in exercising its police powers in stream pollution control. It was during the latter part of this period that activity was started in the interstate area. Actions brought by the State Department of Health and the interstate agencies obligated local government and industry, immediately after World War II, to proceed with the design and construction of adequate sewage and industrial waste treatment facilities.

In some areas of the State, joint action by local governments and industry was indicated. Such joint action involved from 2 to 50 or more municipalities in various situations. This obviously led to political problems and furthered consideration of legislation such as the Sewerage Authorities Law. It is generally recognized by those familiar with joint action by local governments, that difficulties are encountered in securing concurrent action for joint municipal projects. Obviously the problem becomes much greater as the number of municipalities involved increases. The Sewerage Authorities Law was designed to facilitate operation in such joint action. Once created a sewerage authority is empowered to proceed with the solution of a sewerage problem independent of the various local governments which may have been involved in its creation.

New Jersey Experience

What has been the New Jersey experience with sewerage authorities? Have they been a success? Are they a good idea? Will they endure? It is too early, undoubtedly, to provide conclusive answers to all these questions. Some indications, however, seem clear from brief experience.

There are approximately 30 sewerage authorities operating in New Jersey today. The majority of these authorities represent one municipality or a part thereof. Others represent several municipalities, or large segments of whole counties involving 50 or more municipalities. There has been but one instance of the abandonment of a sewerage authority, and this was in one of the smaller municipalities of the State.

As indicated earlier, sewerage authorities have been successful in instituting within only a few years sewerage construction in New Jersey costing more than $125 million. Much of this progress has been made possible because of the facility of a sewerage authority in accomplishing its ends with a minimum of political interference and a minimum of red tape. The Sewerage Authorities Law has made it possible for truly interested local citizens to accomplish sewerage projects in a relatively short time. It might also be said that the law has made it possible for elected local officials to relieve themselves of many of the burdens involved in sewerage projects, by delegating the work to another agency.

Nothing has been accomplished by sewerage authorities that could not have been accomplished by established local government. The question of importance is, would local government have done the job? The New Jersey experience indicates that local government might ultimately have done the same job, but undoubtedly many more years would have been required to accomplish it.

The case against sewerage authorities to date appears to be somewhat as follows:

1. Sewerage authorities represent an undue delegation of authority to a relatively independent agency, and to some degree represent a departure from strictly democratic government.

2. Sewerage authorities can be and in some instances undoubtedly have been expensive. The interest rate on sewerage authority bonds sometimes may be higher than would have prevailed in the instance of municipal financing, because of the fact that the credit of the municipality or other local government unit is not involved in authority bond issues.

3. Sewerage authorities may deny the extension of their services if they believe such extension to be economically unsound, even though it might be indicated as desirable for the general welfare.

Whether or not sewerage authorities endure probably depends primarily upon the qualifications of the membership of authorities, and the members's determination to manage sewerage facilities in a business-like manner. There are some who believe that it is only a matter of time before appointment to a sewerage authority will be dependent solely on one's political loyalty. If this situation should develop, a short life must be anticipated for the sewerage authority movement. Fortunately, there is to date much indication of active interest in sewerage authorities by citizens of the highest calibre. If this situation prevails there is no reason to doubt that the sewerage authority movement will continue to be a real success in New Jersey.

Rates, Revenues, and Rising Costs*

by LOUIS R. HOWSON

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WATER rates are essentially a means of allocating revenue requirements equitably to all classes of consumers. This discussion deals primarily with revenues rather than rates.

Every water utility, if it is to furnish good service must have sufficient revenue to cover [1] all operation and maintenance expenses; [2] depreciation; and [3] fixed charges (or return on investment). In addition, it must earn a surplus large enough to attract the capital necessary for its orderly expansion. The costs of operation and maintenance are in general identical for both privately and municipally owned water works, assuming equally efficient management. Depreciation likewise occurs without regard for ownership, and must be provided for as an annual operating expense chargeable to those using the facilities. The amount of depreciation charged annually should be at least sufficient to maintain the facilities. Although it rarely does so under regulatory commission control, it should also take into consideration the changing purchasing value of the dollar. Regulatory commissions now generally allow 1.5-2.0 per cent of original cost for annual depreciation in fixing rates for private water works. This is approximately equivalent to 0.75-1.0 per cent of the actual current cost of reproduction. Because it is facilities rather than dollars that furnish water service, it is facilities that are consumed and must be replaced when worn out: obviously, they can ony be replaced with current dollars. Accrual of depreciation in amounts sufficient only to repay original costs results in a situation in which future customers must pay part of the cost of present water consumption.

A study made by the author some years ago disclosed that municipal plants which charge depreciation allowances in their operating statements use substantially higher percentages than those fixed by commissions for private utilities. The money thus accumulated is generally used for new construction. This procedure is believed to be in the customers' interest.

The significance of fixed charges to private and public owership differs. The privately operated plant must secure through rates an amount sufficient to earn a fair return upon the fair value of the property; otherwise, it cannot continue to attract capital in competition with other industries. Usually in private operation the state regulatory commissions do not permit more than 60-67 per cent of the capitalization to be in bonds. The earnings in excess of fixed charges are subject to federal income tax at 52 per cent, a charge from which the municipal plant is exempt.

Interest rates on indebtedness of municipal plants are also ordinarily lower because of the fact that income from municipal securities is usually exempt from federal taxation, and frequently from state taxation as well. In many states nothing is paid by municipal utilities in lieu of property taxes which would be paid by privately owned water works.

Both privately and municipally owned water works must earn a substantial surplus beyond the fixed-charge requirements. To make municipal water revenue bonds an attractive investment their annual earnings available for debt service should equal 30-50 per cent more than the annual requirements of interest and amortization. This is also true of the securities of private companies.

Rates Beyond City Limits

In municipal plants, the customers are themselves the stockholders and, as such, entitled to water "at cost"—including in the cost proper provision for financing growth. When all or a part of the investment has been retired from earnings, it is the author's belief that rates within the city limits should include only such fixed charges as are actually paid for interest and amortization on the remaining dept.

Concerning water sold outside the corporate limits, however, it is believed that municipal plants should base rates upon operation as a utility. Such service should yield a reasonable return on the value of the facilities. In a number of cases in which outside rates have been computed at fair return on fair value, the outside customers have been charged at rates 50-75 per cent higher than those within the corporate limits.

Changing Revenue Requirements

No water works is static, even though it serves a community which is experiencing no substantial population growth. Even in such a community, the per capita use of water is increasing, and the standards by which water quality is measured are becoming more exacting with regard to degree of purification, taste and odor requirements, and chemical characteristics.

By the same token, neither are water revenue requirements static. All capital expenditures must be financed, either directly or indirectly, from revenues. The capital investment in water supplies has been undergoing a marked change in the past several decades. About 50 years ago, a Bureau of the Census survey revealed that the book investment in water works at that time averaged about $30 per capita. By 1940 this average had increased to about $75, and at present is probably about $100 per capita. From these figures, it is apparent that book investment in water works has increased, over the last half century, at an average rate of approximately $1.50 per capita per year. Currently, water works construction cost about $200 per capita.

Because it costs approximately six times as much today to provide water for a new customer as it did 50 years ago, it is apparent that old customers are paying a large share of the new customers' water bill. Unless the regulatory commissions and municipal bodies responsible for the fixing of rates recognize that fair value as well as original cost should be considered in determining equitable rates, water works will be subject to a creeping economic paralysis resulting from the dilution of 100-cent dollars with those of continually decreasing value.

Discriminatory Rates

Under usual rate determinations, new water customers are currently enjoying discriminatory rates. The cost of construction at $200 per capita is $800 per new service. Figuring 6 per cent return and 1.5 per cent for depreciation plus operation and maintenance expenses, the new residential customer's payment of $20-$25 per year will not cover more than a third of his cost to the system. The remainder must be provided from revenues

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derived from old customers—a clearly discriminatory practice.

State utility commissions partially recognize this inequity in their rules by declaring that new customers requiring extensions of mains must advance that part of the cost in excess of 2.5-4 times their first year's revenue (that is, all costs over $50-$100). As the average service spacing, even in highly developed areas, is about 60 ft, the cost of a 6-in. diameter main is about $210, and the customer therefore advances one-half to three-fourths of the cost. This amount, however, covers only about a fourth of the total investment in facilities from the source of supply to the service pipe required to serve the new customer.

A possible remedy is a connection charge for all new customers. Otherwise, their deflated-dollar annual revenue will not pay their proportionate share of the inflated investment made for them.

Current Reproduction Cost

During the past 25 years construction costs have increased nearly fivefold. This period, however, covers only about a third of the life-span of most midwestern water works and a fifth or less of that of many water works in the East.

Records of the costs of very early water works construction indicate that with the crude facilities then available it required about the same investment per service as it did 100 years later, although labor rates had increased materially. In the last 50 years, however, there has been a sharp increase.

Water works abandon very little property: accordingly, it is probable that considerably more than 75 per cent of all expenditures for water works construction made in this country during the past 150 years is still in service. This fact has caused much debate in fixing rates for water works service. Practice varies from exclusive use of current cost reproduction (less depreciation) to consideration only of original cost in fixing the rate base.

It is the author's opinion that cost of reproduction is at least entitled to major consideration and accordingly his office has made many cost-of reproduction estimates of water works properties whose original cost is also available. From these studies, made during the past several years of continually increasing prices, it is found that the current reproduction cost (less depreciation) of water works systems is 1.75-2.5 times the original investment made over a period of several decades. The average of six recent estimates was 1.94. The range depends primarily upon the extent to which the property has been expanded during recent periods of high costs. With some of the older properties, built 25-100 years ago, the ratio will be larger—perhaps as high as 3:1. Among recently constructed properties, however—even though some of them have substantially doubled their investment in the 10 years since the end of World War II—the ratio of current reproduction cost(less depreciation) to original cost was never less than 1.75:1.

TABLE I

Growth of American Economy Since World War II

Item	Prewar	1955	Increase per cent
Population—millions	133.8	166.5*	25
Personal incomes—billion dollars	102	315	210
Cost of living†	65.9	114.7	74
Hourly factory wages—dollars	0.66	1.93	192
Wholesale prices†	66.9	112	68
ENR Construction Cost Index‡	235.5	680	188
Water rates	—	—	0-75

*1955 population estimated.
†1947 = 100.
‡Eng. News-Record (Dec. 1955).

Are water works subject to any different economic laws than individuals or corporations?

Are water works receiving adequate remuneration at rates computed upon a base of only half their fair value, when such earnings must necessarily be spent in the open market of inflated prices and deflated dollars?

Is it *dollars* or *facilities* that furnish the service and are exhausted by use?

When commodities, facilities, or structures are traded in at sufficiently frequent intervals to establish "market value," the trading prices reflect the current purchasing value of the dollar. Unfortunately, water works are rarely bought and sold, and in order to secure a measure of their present value, estimates of reproduction cost (less depreciation) at current price levels are made. Some regulatory commissions give little weight to such estimates. Probably few water works would contend for immediate adjustment of rates to reflect fully the current cost of reproduction. It is interesting to note, however, that in cases where a city acquires the water works property it almost invariably pays a price based largely or entirely upon cost-of-reproduction estimates—even though it may have argued for original cost as a basis for rates for the private company.

If water works facilities were as short-lived as telephone or electric power facilities, the difference would not be so great, but with two-thirds of water works value in the long-life distribution system, and an overall system life as much as ten times that of some other utilities, the water works industry must have consideration from the fair value viewpoint if it is to meet its requirements satisfactorily.

The figures in Table 1, derived from *The Magazine of Wall Street* illustrate changes in the American economy since the beginning of World War II.

Operation and Maintenance Costs

Every water works has been experiencing a rapid increase in the cost of operation and maintenance, particularly in the last 10 years. Table 2 shows the reported increase of plants in several cities. From this table it will be noted than in the 9 years following World War II operation and maintenance expenses per unit output have substantially doubled. Because operation and maintenance expenses represent from 50 to 70 percent of the total cost of operating most water works properties, it is apparent that rates which were adequate 10 years ago are no longer sufficient.

Comparison was made of the *ENR* (*Engineering News-Record*) Construction Cost Index with the records of Chicago, Louisville, and Des Moines for operation and maintenance expenditures per million gallons for the period 1945-54. Although the increases for the individual cities varied, a plot of the average increase of all three generally followed the *ENR* increase curve, but was about 10 per cent lower.

Inasmuch as operation and maintenance costs have substantially doubled in recent years and require 50—75 per cent of water works revenue, it is apparent that to compensate for this element alone a 25—35 per cent increase in revenue per million gallons would be necessary in this period merely to maintain the position of 1945.

Capital Additions

In the 25-year period prior to 1945 the water works industry was expanding $7.35 per customer (or about $1.75 per capita) per year from earnings to finance new construction. This was about 25 per cent of the gross revenue. Assuming no change in rate of growth, this expenditure would now—as a result of rising costs—be at least $18—$20 per customer, an increase of about $12 per customer over 1945. This $12 is equal to 37.5 per

cent of the 1945 average revenue per customer. Many water works have increased rates since 1945, of course, and this $12 per customer increase would probably be equivalent to about 25 per cent of current average revenue. Capital improvements must be made. Inasmuch as financing from current revenue is usually about 40 per cent less costly than financing from funded debt, it is obvious that revenues should be sufficent to finance as much new construction as possible from earnings.

In 1945 the average water works had $7.50 per customer left from earnings each year to cover fixed charges, return, and similar items. Even assuming that this amount is adequate for 1956 it is apparent from the foregoing that 1945 water revenues would have to be increased 25—35 per cent for higher operation and maintenance costs plus about 37.5 per cent more to maintain construction progress—or a total of 65—70 per cent, as a general average.

Many water works have had substantial rate increases. Some private companies have had two—and a limited few, three—increases, but there are still many water works trying to maintain service at pre-World War II rates. In general this is impossible, and to attempt it is usually unwise; almost without exception it results in inadequate service, dissatisfied customers, and the overlong deferral of necessary plant expansion. Within recent years practically all important water works construction programs, whether public or private, have required increased revenue before they could be economically financed.

From a rather inadequate sampling of plants for which data were readily available to the author it would appear that the average annual revenue per customer has risen from $32.10 (the average of 100 plants studied in 1945) to $50-$60 per year in 1955. The 1955 per capita revenue is probably about $12.50 per year.

In three recent rate cases involving private water companies in three different midwestern states the regulatory commissions' decisions resulted in gross revenues of $65.33, $87.07, and $65.50 per customer. In 1945 these three companies had gross revenues per customer of $38.47, $42.30, and $32.40, respectively. The average of the increases for the three companies in the 10-year period was 93 per cent. These companies have the advantage of alert management responsive to the need of maintaining earnings sufficient to attract the capital necessary for their rapid growth. Their per customer revenues and their 10-year increases are probably materially greater than the national averages—but no doubt reflect fairly well what those averages should be.

TABLE 2
Increase in Operation and Maintenance Costs, 1945-54

Plant	Ownership*	Cost Increase per cent 1945 avg
A	M	202
B	M	180
C	M	178
D	P	169
E	P	168
F†	M	130
G†	M	132
Avg Plants A-E		180

*Municipal plants designated M; privately owned, P.
†Gravity supply.

Forecasting Needs

It is just as essential for a water works to study its requirements and provide for them in advance of their maturity as it is for an individual to plan ahead. This is particularly true in areas of rapid growth.

Every water works should periodically have its needs projected into the future for at least two decades: the required new construction outlined, construction costs estimated, and the impact of those costs (along with changes in operating procedures) on the total annual expenses estimated. Construction expenditures should be coordinated with revenues as far as possible, and rates should be charged as needed to maintain high service standards.

Water is cheap, and experience has usually shown that the people will vote the necessary bonds or approve rate increases when they are convinced of the necessity. Unless they are so convinced, as is illustrated by the experience of Denver, Colo. The voters of that city defeated a $20,000,000 bond issue and a year later—after a comprehensive survey and report and an effective educational campaign—approved a $75,000,000 issue by a 14-to-1 margin.

Electric Utilities

Analysis of the operation statistics of five electric companies in four midwestern states serving about 1,500,000 customers discloses revenues from residential customers varying from $70.65 to $83.06 per year, and averaging $77.96 per year. This is at least three times as great as the average residential water bill in the same area. These electric companies have grown so rapidly that the average dollar age of their investment is less than 10 years (about a third that of the average water works) and their revenues are 2.6 times as much as they were 10 years ago. There would appear to be little reason why consumers would not be willing to pay as much for water as for electric service, if they were convinced of the necessity. Possibly one element in this situation is the fact that 80 per cent of water works are publicly owned, and politicians are more allergic to rate increases than are stockholders.

Conclusions

1. Water rates in general are too low. More adequate revenues would be in the interest of both the water supplier and the water user.

2. As a general statement it is believed that, under conditions now prevailing, a minimum charge of less than $1.50 per month, permitting the use of 2,000 gal of water per month, cannot be equitably sustained for most water works. As an indication of the reasonableness of this statement, regulatory commissions in three midwestern states have recently fixed minimum charges for 5/8-in. meters for major water utilities of $2.22, $2.60, and $2.83 per month, respectively.

3. Since half of all residential consumers in nearly all cities use less than 3,000 gal per month, the amount of water furnished under the minimum rate should be reduced to not more than 2,000 gal per month. A 300-gal per month allowance offers no incentive for water conservation to nearly half of the residential consumers.

4. The public wants adequate water service. The average domestic service throughout the country uses about 6,000 gal per month, for which the customer currently pays $20-$25 per year. An increase of about one cent per capita per day would increase the residential revenue more than 50 per cent. Corresponding percentage increases in industrial and commercial rates would produce sufficient revenues for most plants. This seems a small price to pay for the difference between good and mediocre—or even unsatisfactory—service.

5. Good water service requires good management. Good management studies water requirements in advance, provides for meeting expanding needs before they mature, coordinates construction and financial programs, acquaints the public with financial requirements for good service, and provides the facilities before an actual emergency develops.

6. Adequate revenues today are the best assurance of satisfactory water works service tomorrow.

Sewer Rentals and Sewer Extension Charges in Massachusetts*

by CLARENCE I. STERLING, JR.

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THE DIVISION of Sanitary Engineering of the Massachusetts Department of Public Health receives many inquiries each year in regard to financing sewer extensions, house connections and the maintenance and operation of systems. With rapid expansion of sewerage systems due to mass movement of the citizens to suburban areas, the problem of financing such extensions to serve newly developed areas has become acute. Although in the final analysis, the cost of sewerage services is borne by the citizens of the community, nevertheless, each community attempts to develop some formula of painless financing.

In Massachusetts the methods of financing sewerage systems are provided for in Chapter 83 of the General Laws. The cost of construction of sewerage systems is financed by serial bonds, the maximum period not to exceed 30 years. The General Laws provide, however, that the city shall be assessed not less than one-fourth nor more than two-thirds of the cost of laying out, constructing, maintaining and repairing common sewers. Many of the sewerage systems in Massachusetts have been in existence for a number of years so that the rates that have been established by the municipalities are frequently not realistic when compared with present day costs.

In an effort to secure information that would be helpful in guiding municipal officials in setting up realistic tariffs, a questionnaire was sent to all municipalities having public sewerage systems. The response to the questionnaire was excellent.

Financing Sewer Extensions

A study of the questionnaire showed that sewer extensions were financed in five different ways with some minor variations. Thirty-nine municipalities financed sewer extensions on the front foot basis; five municipalities financed on an area basis, usually with a maximum chargeable depth of 100 or 125 ft. for the property; 28 of the municipalities financed on a combination of the front foot method and the area method; 54 of the municipalities financed their extensions directly from general taxation with no specific charges to the persons directly benefited, while three municipalities assessed the actual cost of the construction directly on the persons benefited.

In the case of new subdivisions, 60 of the communities required that the sewers be installed and paid for by the developer, while 31 municipalities did not have such a requirement.

Section 21, Chapter 83 of the General Laws states that if land abuts upon more than one way, assessments for sewers based wholly or in part upon frontage shall be assessed upon the frontage upon one such way and upon so much of the frontage upon such other way as is not exempted by the board of sewer commissioners whose duty it is to make the assessment, and such board may exempt from assessment so much of the frontage upon such other way as they consider just and equitable.

Seventy-nine of the communities submitting answers to the questionnaire gave their solution to the problem of corner lots. There were 15 different solutions, as follows:

1. Assessment based on the shortest frontage.
2. Assessment based on the longest frontage with a maximum of 100 ft.
3. Assessment based on one-half the frontage on each side.
4. Frontage assessment which exempts 100 ft. on the short side.
5. Frontage assessment which exempts 50 ft. on one side.
6. Frontage assessment which exempts 60 ft. on one side.
7. Frontage assessment which exempts 80 ft. on one side.
8. Frontage assessment which exempts 100 ft. on one side.
9. Frontage assessment which exempts 125 ft. on one side.
10. Frontage assessment based on the longest side or the side on which the sewer connection is located.
11. Frontage assessment based on the side with sewer connection.
12. Frontage assessment based on the longest frontage.
13. Assessment based on exemption of the shortest side.
14. No frontage exemption on either side.
15. Assessment based on exemption of 100 ft. on the longest side.

In regard to financing sewer connections, the law was recently changed so that now the property owner may take up to 10 years to finance both his house connection and the sewer charges at 4 per cent interest. The questionnaire showed that there were five methods of making charges for house connections. These were on the basis of (a) actual cost, (b) a fixed sum, (c) a unit foot cost, (d) general taxation or (e) paid for by the property owner.

Financing, Maintenance and Operation

The financing, maintaining and operation of sewerage systems are done by any one of three different methods or a combination of the methods. These methods are (a) general taxation, (b) fixed charge for each service connection or family, or (c) a charge based on water consumption. In the latter method the rate may be a percentage of the water bill or it may be a fixed rate per 100 cu. ft. as based on water meter readings. In the case of large installations the sewage flows are metered directly and the charges based accordingly.

Summary

A reveiw of the data obtained from the 133 questionnaires returned would indicate that there is a need for a study to develop more uniform and realistic methods of financing sewer extensions, house connections and the cost of maintenance and operation of sewerage systems.

Editor's Note—Copies of the tabulated data obtained from the questionnaires can be obtained directly by writing to the author, Massachusetts Department of Health, 511 State House, Boston 33, Mass.

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Better Administrative Practices*

by M. J. SHELTON

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THE water works manager normally looks to the customer and taxpayer for additional income to meet the continually increasing expenses of operation. The reduced purchasing power of the dollar and the growth in water demand since the end of World War II have combined to make this basic problem more pressing than ever. Many utilities have tried to get along on their old rates, reducing their expenses by eliminating certain services formerly rendered and by postponing maintenance and replacement. This apparent economy actually becomes a greater burden as time goes on. Still, the necessity of raising rates is a difficult one to face, and, in the presence of adverse public reaction, the governing body usually postpones the increase. The La Mesa, Lemon Grove, and Spring Valley Irrigation Dist. has been confronted with such a problem, and the purpose of this paper is to describe how improved administative practices have enabled the district to give service without raising rates, despite a tremendous rise in demand.

The district, which is located to the east of and adjecent to San Diego, Calif., contains 22,651 acres, including a population of 67,000 in 1952—more than 5½ times the 1940 figure. As a result of this urbanization, the district has been forced to convert its operations from irrigation to domestic water supply.

In 1945 the district had one engineer, its manager. Problems brought about by the rapid growth made necessary the addition of qualified engineers, so that operations could be analyzed, additional records developed, and facilities properly designed, on the basis of adequate board of directors has established additional rules and regulations resulting in higher standards, equitable division of costs, improved public relations, and greater personal efficiency. In 1951 the board employed an administative consultant to make a study of office procedures and recommend improvements. The report was submitted in June of that year. Nearly all of the recommendations have been adopted, and many other changes have been made. The cost of the survey was small, particularly when compared with the tremendous benefits that have been realized.

Shortly after completion of the administrative survey, the position of business manager was created. He works closely with the general manager, being responsible for administrative details such as personnel, accounting, billing, purchasing, warehousing, office procedures, and customer relations.

It was determined at the outset that a given procedure or operation would not be accepted as necessary merely because it was long established. Starting with the most flagrant deficiencies, changes were brought about within the office and in the field, and even basic policies of the board of directors were reviewed. In consequence, duplication of records has been eliminated; greater labor efficiency has been achieved through motion studies and increased machine operation, with a resulting reduction in both field and office personnel; extension policies have been improved; a clear-cut budget control procedure has been adopted; an entirely new system of map records has been instituted; suggestions from employees have been encouraged by awards for those accepted; and, most recently, a pension system has been instituted, providing additional employee benefits that will still further decrease an already very low labor turnover. Some indication of the monetary value of these changes is given by the fact that the cost of water delivered to the consumer dropped from 17.2 cents per 100 cu ft in 1948 to 14.0 cents in 1952. During this period the district was also replacing many obsolete pipelines and generally improving water quality, quantity, and pressure—actually at a pace greater than the growth of the population.

Technological advances are facilitating, and changes in public attitudes and demands are constantly requiring, higher standards and better service. In such circumstances, obsolescence is normal, but it may arrive more rapidly than expected. The problem of management is to establish methods of detecting it, to maintain alertness, and to revise operations and procedures as appropriate.

Organization and Personnel

As previously indicated, the district is governed by a board of directors, consisting of five men whose terms are staggered. Elections are held every 2 years and the members serve for 4 years. The board operates in the same manner as a city council, under a section of the California water code governing irrigation districts. An assessor-collector-treasurer is also elected, and the board appoints an attorney, secretary, general manager-chief engineer, and business manager. The rest of the employees in the organization are hired by the latter. All operations are carried out on a 40-hr week basis, including those of emergency crews. Overtime is held to an absolute minimum.

Engineering has played a most important part in the district's activities in the past few years because of population growth in the area. That department has, therefore, been enlarged, whereas all others are actually smaller than they were a few years ago. Although the number of accounts has more than doubled since January 1948, the district has added only one employee to the main office staff and one to the outside force.

One of the first steps taken was to review the existing salary schedule to see that it was reasonably in line with that prevailing in other public bodies in the area, making due allowance for such differences as the absence of a pension system for district employees. After 1951, when district employees were first covered by the Federal Social Security System, it became feasible to establish a retirement system, which had previously been precluded by the large number of employees with long service. Such a plan was initiated in 1953, with 95 per cent participation on the part of those eligible.

The district now follows a general policy of employing younger people and tries to obtain college men for the

*Reprinted from the Jour. Amer. Wat. Wks. Assn. Vol. 46, No. 6 (June 1954) by permission of AWWA.

more important positions. Experience has shown that the additional amount paid for a better qualified person is more than offset by his greater effectiveness and adaptability.

An innovation started in 1951 was an employee grading and interviewing system. Each foreman grades his men in every 6-month period, and his report is reviewed by the superintendent, who makes notations before turning it in to the business manager. The latter then personally reviews the grading sheet with the employee in a private conference; in addition, he asks for any criticisms or suggestions that the employee might have. These interviews have been most beneficial in improving personnel relations and developing better operations. Upon completion of the reviews by the business manager, he meets with the superintendent and general manager to go over each man's record and determine whether he is to be recommended for an increase in salary. The recommendations are then presented to the board of directors for formal action.

Office Rearrangement

An early change was the complete rearrangement of the office. In the past, there had been an aisle down the middle of the office, dividing it into two parts. On one side was the "water department" and, on the other, the "tax department," each with its own counter and collectors. The result was that the public would often call at the wrong department and have to be referred to the right one, making for lost motion on the part of an employee, as well as inconvenience to the customer. Even more important was the fact that the employees of one department were never used to relieve the work load in the other.

Under the new arrangement, the two departments were combined into one. Small separate offices were eliminated and the business manager was located at the rear center, where he could oversee all activities. The counters have been attractively redesigned, and the telephone switchboard is now situated near the main entrance, so that the operator can also serve as information clerk. Full use is made of the time of all employees, work assignments being given out by the chief clerk. In accordance with the findings of motion studies, desks have been so placed that a person takes as few steps as possible to perform his job. Maps are easily accessible to both the public and the employees. A drinking fountain formerly installed at the rear of the office for personnel use has been moved to the front, so that visitors can drink the water which is delivered by the district —a worth-while public relations device. A single clerk has been placed in charge of a central file, thus minimizing the possibility of misfiling while greatly cutting down the time consumed in locating documents.

Each person in the office is assigned a primary function but works at other positions for a sufficient time to become thoroughly familiar with them. This policy of understudies for all operations has been applied in every section, both in the office and in the field. A written job description, describing all functions or duties, has been drawn up for every position, thereby further insuring continuity of action in the event of absence of an employee.

Forms

The administrative survey had indicated considerable duplication and lack of coordination in the preparation and use of forms. The business manager obtained a copy of every form in use and began a study to see whether it was necessary, what was done with the information, who received it, and whether it was temporary or permanent. Interviews were held with the persons who regularly initiated or received the farm to determine if it could be eliminated, combined with others, or simplified. The number of forms in use was reduced materially, saving labor, time, and filing space.

Standard Procedures

As the administrative modernization got under way, it became apparent that there should be a permanent system of advising all affected persons and at the same time making available for the future a ready reference source on policies and procedures. This was accomplished by the issuance of executive orders, standard practices, board memoranda, and the like. Department heads receive copies as issued and place them in a loose-leaf book, where they are easily accessible.

Machine Operations

Before the administrative survey was made, the single billing machine on hand had to be operated overtime to keep up with the billing schedule. A review of billing practices simplified the work, eliminated some steps, and made possible the preparation of all bills well within regular work hours. The meter reader's sheets were revised to assist both him and the billing-machine operator. The bulky, large-size individual water account cards formerly kept on permanent file have been eliminated. Billing data are now printed on a small card simultaneously with the customer's bill. The cards are destroyed after a year, as a permanent record is still available in the meter book. Calculating machines, typewriters, and other such equipment are replaced on a regular schedule in order to obtain maximum efficiency.

A wire recorder, acquired to save stenographers time in taking dictation, has also proved valuable for recording telephone calls and conference discussions. A photostat machine is used to make copies of maps, letters, and other documents, and a blueprinting machine in the engineering department can likewise be employed for this purpose.

Improvements in machine operations were not limited to the office, but were made in the field as well. In this connection, the board of directors' policy of awards for suggestions has proved fruitful. A wagon drill has been adapted for drilling services under roads, with very great savings in time, labor, pavement repair, and inconvenience to the public. A small service trenching machine was developed, and study is being given to a drill that will permit the placement of a new copper service inside an old galvanized-iron pipe.

Collections

It has always been recognized that peaks in office routine should be eliminated. To this end, the district has for years contracted with banks and drugstores to serve as collection stations. This policy has been extended to include express offices, which will receive payment at any of their branches, regardless of location. All bills carry a listing of the collection stations, as well as a note recommending payment by check. This campaign has increased collections through these media, so that the growth in the utility's business has not necessitated adding more tellers at the office. In fact, the number has actually been reduced by one, as a result of the office rearrangement.

Calendar Check List

The job descriptions mentioned earlier indicate when a certain report is due, when contact is to be made, and the like. As a further safeguard against oversights, the business manager maintains a calendar of such items. Related matters, such as fire and property damage insurance, are now attended to on the same date, if practicable. The business manager, through the chief clerk, reminds the persons concerned well in advance of due dates.

Budget

Although, in the past, an annual projection of expected revenues and expenditures was made by the district, no true budget was prepared. It is now the responsibility of the business manager to coordinate the efforts of all departments in the preparation of such a budget and to maintain control throughout the year. Every department makes a careful study and tabulation of the anticipated work, giving costs and justifications. This information is brought together by the business manager, who, after thorough analysis, reviews it with the general manager. The entire budget study is then presented to the board of directors and examined in detail with them at meetings held during June. After final adoption by the board of directors, the budget is used as a guide in authorizing construction projects or purchases involving capital outlay as they come up. Two years of experience with this procedure indicates that all department heads cooperate fully, that there is improved coordination in the planning of projects, and that less work is performed and charged to so-called maintenance accounts, resulting in very substantial savings.

The district system still has many miles of substandard pipe in service, acquired from existing utilities when the district was formed. This condition, together with the very rapid development of the area, often necessitates unanticipated expenditures. Consequently, the budget includes a considerable fund to meet such situations.

Communications

For a number of years, the district has maintained six radiotelephone-equipped cars, this utility having been one of the first to take advantage of the service when it was introduced by the telephone company. With expanding operations made necessary by the growth of the area served, it was determined to increase the number of radio-equipped cars to a total of twelve. A thorough study showed that twelve three-way radio units would approximate the cost of six additional radiotelephone units installed by the telephone company (based on a 10-year life, with full allowance for maintenance, depreciation, and other expenses). The principal argument for conversion to the three-way radio was the fact that the radiotelephone channels had become overloaded, often causing long delays. Although a radio unit is not in contact with all land phones, this disadvantage is offset by the ability to hear the conversations of all other units and thus keep abreast of the situation. Furthermore, the radio cars can communicate not only with each other but also with the telephone operator at the base station, who normally handles customer calls.

Emergency calls from customers during off-duty hours present a problem. In the past, the district listing in the telephone book included the home numbers of all emergency personnel, as well as the superintendent. The result was that a customer often had to make several calls to reach an employee on standby duty. Retaining an employee at the office or shop at all hours would have been far too expensive, and it seemed impractical to have the police receive the calls. The solution adopted was to arrange for all off-hour calls to be taken by an answering service, at a cost of only $25 per month. The district informs the answering service of the names, responsibilities, and telephone numbers of men on standby duty, so that the telephone operator can get in touch with the right person, depending on the nature of the complaint. In this way, off-duty men get their rest and the customer has to make only one call, which is handled by a trained operator. This service has been in effect since the beginning of 1953 and has proved to be very satisfactory.

Leasing of Automotive Equipment

Detailed analysis indicated that the district might be able to lease automotive equipment at a saving over the former plan of operating its own fleet and shops. After considerable negotiation with a number of possible bidders, the district contracted with one of the local dealers for 29 vehicles, ranging from sedans to flat-bed and dump trucks. The sedans and pickups are furnished on a 2-year replacement basis, the larger trucks on a 3-year basis. The dealer makes all mechanical repairs, supplies oil, batteries, and tires, and services the vehicles in the district's yard at the close of the day. The district furnishes gasoline and insurance only.

The benefits from this program are numerous: the district always has a modern fleet, which makes a good impression on the public; delays due to repairs are at a minimum; labor time equal to that of 4½ men is available for other purposes; the shop need be used only for preventive maintenance on heavy construction equipment; administration by the management and superintendent has been eliminated; purchase orders have been reduced one-third; and inventories of repair parts and tires are unnecessary, thereby releasing funds for other projects. All this has been accomplished with the same cash outlay as was required by former operations, but funds previously tied up in capital have been released for water main installations. A further advantage of the new procedure is that the costs are known in advance for the entire year, payments being made monthly at a fixed rate per unit. It is planned to place all automotive equipment, except that for heavy construction, on a lease basis within the next year.

Distribution System Records

Conversion from irrigation to domestic service has brought about many changes in the district's distribution system, which, in turn, have necessitated the development of a master plan that is annually reviewed and amended to meet new conditions. System records are the full-time responsibility of one engineer, who checks all facilities installed and keeps up with current construction. Drawings and descriptions are prepared to predetermined standards and are filed and indexed for ready reference. The photostat machine is used to reduce record drawings to the property scale, and additional data are drawn on the prints. This procedure eliminates 75-80 per cent of the drafting work and expense.

To replace the cumbersome and sometimes inaccurate maps that have been maintained since the inception of the district in 1926, a map-making project was started in July 1952. All base sheets are now completed and in use in the tax department. New wall maps are also in use, and pipeline data are being recorded on a second set of tracings. Meters are located relative to property lines; the size and type of service, the account number, and the address are shown; pipeline data include the date of installation, size and type of pipe, work order number, and location relative to centerline. Elevations are shown wherever such data are available, and eventually it is planned to include contours. Full use of the photostat machine has been made in reducing layout time by bringing record maps into the proper scale, so that they can be traced.

An attempt was made to contract the entire project, but none of the regular map-making companies was interested and one local engineering company's bid was so much higher than the estimated cost that the board of directors authorized performance of the work by district forces. The project is set up as a special department, removed from other activities, so that the work can be carried on without interruption. To date, prog-

ress and costs have been well within the estimates.

Extension Policies

The board of directors has established basic policies pertaining to granting of service to customers who do not front on pipelines, as well as regarding the installation of facilities in new developments. In the former, the district requires the owner to sign an agreement stating that, when and if a pipeline is installed, he will pay front-foot costs based on 6-in. pipe. The document is recorded, and each prospective owner of property so covered is informed of his responsibility whenever a title search is made. Upon the signing of such an agreement, temporary service is given from the nearest main.

Whenever an individual or developer inquires about new pipelines, the engineering department prepares a cost estimate and makes a schematic layout indicating the size, location, and type of pipe, and the location of valves and fire hydrants. This information is shown on a printed form, which is furnished to the person inquiring, with copies being placed on file. The owner must employ a private engineer and contractor, as the district does not do any construction itself, with minor exceptions. Payment of the estimated cost must, however, be made to the district before work can start, and the owner has to send the district a form letter stating the name of the contractor, the amount of the contract for installation, the expected date of starting and completion of the job, and the name of the party to whom the district is to make payment. Thus, the contractor is assured of payment, and the work is performed according to plans approved by the district. Any funds not needed are returned to the owner upon completion and acceptance. The district makes spot checks to determine that the facilities are installed as planned. The district disinfects the new lines and makes the connection to the system. All other work is done by the contractor, including excavation for the district main connection. By following this policy of having the owner finance the extension himself, the district can conserve its funds for necessary projects.

The results of the administrative changes described have been gratifying, but a constant search for means of further improvement is being maintained. It is hoped that other utilities will find application for some of the measures that have benefited the La Mesa Dist.

R&D

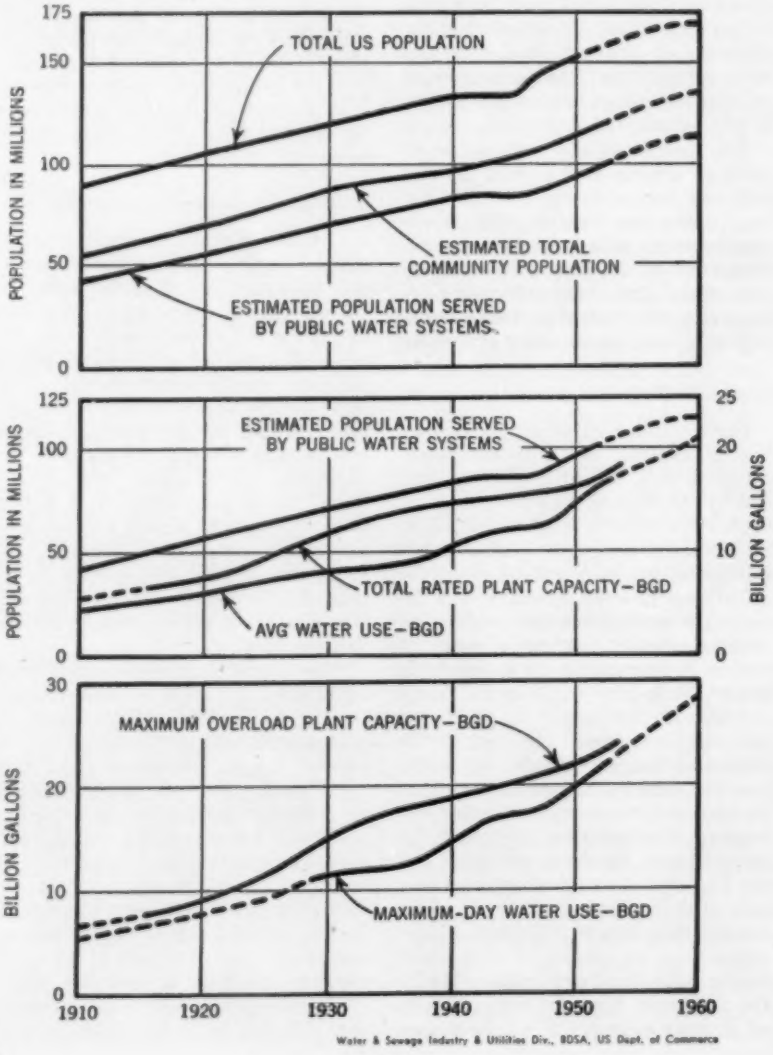
What's Happening In Water Works

The wide-awake water works manager must consider the future demand on his water supply system. This too, is part of "Better Administrative Practices." It is not enough for a manager to develop an organization and personnel, to arrange the office efficiently, to develop forms and standard procedures, to institute machine operations, to prepare a budget, to develop communication systems, and to maintain distribution records. The astute manager, today, must be thinking and planning in terms of the future supply and demand.

The importance of the matter of supply and demand is shown by the charts herewith. These charts were prepared by the Water & Sewage Industry & Utilities Division; BDSA, U. S. Dept. of Commerce. The charts were distributed by the Amer. Water Works Assn. with the timely heading, "WAKE UP WATER WORKS—See What's Happening!"

AWWA added these comments: "Water use is increasing more rapidly than population"—"The Public Wants Service!"—"Water Works Must Meet the Needs!"

These charts bear repeated consideration and study. Each water utility should apply the same criteria to its own facilities and do some constructive planning for the future.



Public Relations in Sewage Treatment Works*

by GEORGE T. LOHMEYER

Superintendent, University of Florida Sewage Treatment Plant, Gainesville, Fla.

FEW SHORT schools for water and sewage treatment plant operators are scheduled today without including the topic of public relations. Why do the planners of operator training courses include this topic? Why is it important?

One main reason this topic is generally included is that the experienced sewage treatment plant operator demands it. The topic is important because without paying attention to improving plant public relations, even the veteran plant operator will be handicapped in meeting his responsibilities.

Public relations refers to the overall feeling the citizens in a community have toward the local sewage treatment plant. This feeling can vary from complete indifference, which is the general public attitude if the operation of a plant is completely satisfactory, to bad, if a plant has given the slightest grounds for complaint. No treatment plant has or will have a commendable public relations program without directing some effort towards this goal. It will never just happen, work is required!

With the exception of rare geniuses, few successful men in history have been able to completely ignore the public. Large industrial concerns and branches of the armed services have public relations experts whose fulltime jobs are to improve relations with the public.

The attitude the public feels toward a sewage treatment plant can affect that particular plant's operation in several ways. Although a number of privately owned and operated sewerage works are in existence, the majority of such services are provided by municipally operated utilities. The elected or appointed officials charged with setting up budgets for these facilities have an easier job if the public has a high regard for the sewage treatment plant.

Plant Appearance

Beautifying a plant exterior must not be overlooked in bettering public relations, even though a large part of the public will unfortunately never take the time to observe a plant first hand. They will never see the excellently prepared monthly operation report, and if they did it would be of little significance. What the public sees on the outside will be the basis for its judgment. Consequently, it behooves every operator to create a plant of pleasing exterior qualities. Would a visitor to your plant today find a well graded and planted lawn surrounding a neatly painted control building and treatment units?

"Beautifying a plant exterior must not be overlooked in bettering public relations"

Operator Appearance

In sewage treatment, as in all jobs, there is no place for untidiness in the appearance of employees. An excellent impression given a plant visitor by a beautiful plant exterior can quickly fade if the plant operators are sloppy in appearance. Several Florida sewage treatment plants furnish operators with laundered white uniforms. Naturally, visitors are impressed with so fine a showing of organized neatness. Uniforms are not absolutely necessary, all that is required in this respect is that the operators work in clean clothes, and by all means come on the job with a clean shave. An operator who is dirty and unshaven ruins not only the prestige of his own plant but the prestige of his profession as well!

"In sewage treatment, as in all jobs, there is no place for untidiness in the appearance of employees"

Plant Courtesy

Regardless of the importance or seeming unimportance of a visitor to a treatment plant (and who can be a judge of this) each person should be treated with the utmost respect and courtesy. Operators too busy at the time to properly show a visitor through the plant should invite the person to return at a more convenient time. Every plant should have a visitor's registry and every visitor should be invited to sign. Visitors should be made to feel that they are welcome and their visit appreciated. Furthermore, every question asked should be answered with tact and respect.

A good operator naturally reveals that he is proud of his job. He realizes his work is one of the most important phases of public health and for that matter preventive medicine itself. How can a citizen-visitor feel proud of the local sewage treatment plant if the man who shows him about the plant creates the impression he is on the job only to draw a pay check.

Use of Proper Terms

Plant visitors are impressed not only by the treatment facilities but by the manner in which the plant is described. Thinking operators have found it wise to arrange standard "tours" for displaying their treatment plants. In showing a visitor through a plant it is best to follow the flow-through route. Each treatment process, type of sewage treatment plant and treatment unit has a proper technical name. Only the correct terms should be used in describing the plant.

An operator should know more about his plant than anyone else. Ready answers should be given on questions pertaining to the plant history, design engineers, the builder, design capacity, capacity of units, analyses of the raw and finished product and other details of the plant units.

* Reprinted from Sew. & Ind. Wastes, Vol. 28, No. 6, p. 810 (1956)

Plant Interest

In addition to maintaining a sewage treatment plant attractive by keeping it immaculately neat, it is also possible to make it interesting. Visual aids, displays and diagrams have been prepared by alert operators to make their plants more easily understood by the layman. An aquarium of tropical fish provides a point of keen interest to anyone. But consider the significance of such an aquarium, in a complete sewage treatment plant, that is fed by the plant effluent (before chlorination, of course.) Displaying plant models or a series of pictures taken during various stages in the plant construction has been found effective in creating interest. Flow-through diagrams of the treatment units or maps of the city and its sewer system also are helpful.

The average lay visitor does not appreciate the technical nature of sewage treatment plant operation. There is a tragic lack of understanding on the part of the public as to what is being done by various agencies, institutions and professional societies to improve the general quality of operation. Operators can do much to assist in this endeavor by displaying plant operation awards earned by their plant, together with individual certificates of operation earned by plant personnel. Certificates of membership held by the operating personnel in the various professional societies likewise should be on display in a prominent place.

"The average lay visitor does not appreciate the technical nature of sewage treatment operation"

Off-the-Job Relations

The attitude of the public towards the local sewage treatment plant may not be obtained entirely by in-plant activities. The people of the United States found after the last war that some of their best ambassadors were G.I.'s who were constantly meeting the citizens of other countries. In the same way, a plant operator in his off-duty hours can do much to better the feeling the public has towards the operator's occupation. In his church, in his local businessmen's club, and in all phases of community activity the plant operator can do much to forward good public relations.

Public relations is a frequently used term. On a personal basis good public relations comes naturally to some people. They are the ones voted in their school classes as most likely to succeed. However, to others maintaining good public relations is a real effort, but it is a program that will pay dividends.

Dollar Savings Through A Sound Safety Program

by WENDELL R. La DUE

Chief Engineer and Superintendent, Bureau of Water Supply, Akron, Ohio

ALTHOUGH the title of this paper may sound as though it could develop into a mercenary approach to a very human problem, such could not be farther from the truth, either by implication or intent.

At the start, consider a very hypothetical, but nevertheless by no means unusual or impossible, industrial accident case—say of Sam Brown. It has been Mr. Brown's grave misfortune to have lost an eye. The details of the accident are matters of record, and regardless of all statements as to possibilities, Mr. Brown is still at the position where one of his eyes has been irretrievably lost. The proper body of the Industrial Commission of the state has reviewed the facts, statements, and exhibits, and has determined that Mr. Brown has sustained a permanent partial disability, worthy of cash compensation to the amount of several thousands of dollars. The case is closed.

Many of Mr. Brown's friends and fellow employees have said, with a striking degree of reality: "Can anyone or any group set a money value on such a loss?" Truly no one or no group can answer in the affirmative. In fact, Workmen's Compensation has never been considered, nor can it be, a payment in full restitution. As in all types of insurance—fire, life, health, accident—the best it can do is to recognize the frailties of human nature and the inadequacies of solutions of very personal problems and, at best, try to compensate for a loss by recognizing that there always will be those who care.

In Sam Brown's case everybody connected with the case lost. Every disabling injury sets up a chain reaction which spreads and envelops a convincing array of contacts, developments and reactions.

There are direct costs; compensation premiums, doctor bills — both medical and surgical—hospitalization and nursing fees.

Indirect costs by the dozens include loss to the employee, the employer, and his fellow workmen, as follows:

1. Losses to the employee:
   (a) Loss of wages due to time lost from work.
   (b) Drain on the economic position of the family due to unusually large bills.
   (c) Eventual permanent reduction in the injured employee's ability to continue to provide for his home and his family.
2. Losses to the employer:
   (a) Loss of a valued and efficient employee.
   (b) Break-up of the team-work of a work crew.
   (c) Disruption of production by damage or lay-up to valuable machinery, tools, and equipment.
   (d) Disruption of time and productive efforts of the supervisor and cooperating employees.
   (e) Loss of stock due to shut-down.
3. Losses to the fellow employee:
   (a) Loss of time due to shut-down.
   (b) Loss of wages due to loss of work.
   (c) Reduction in productive power due to the loss of a valuable member of the team.

From this brief outline it can be observed quite readily that dollar loss is only a part of the reaction. Every disabling injury imposes direct financial loss to the employee (the victim), to the fellow employees, to the utility, and indirectly to each customer of the utility. Yet dollar loss has proven to be the incentive by which some measure of relief has developed.

At the outset attention was called to a hypothetical industrial accident case, for instance, operating under the laws of the State of Ohio. One clause of the law is worthy of inclusion here as follows:

Section 1465-83 G.C. (4123.39 R.C.)

The amount of money to be contributed under section 4123.38 of the Revised Code by the State itself and each County, and each taxing district within each County shall be determined by the Industrial Commission. In fixing the amount of contribution to be made by the County, for such County, and for the taxing districts therein, the Commission shall classify Counties and other taxing districts into such groups as will equitably determine the contributions in accordance with the relative degree of hazard, and shall also merit rate such individual counties, taxing districts, or groups of taxing districts in accordance with their individual accident experience so as ultimately to provide for each taxing subdivision contributing an amount sufficient to meet its individual obligations and to maintain a solvent public insurance fund.

Most business managers of water utilities are familiar with the techniques of procedure of Industrial Commissions. Nevertheless, most represent utilities which have not yet taken advantage of the clauses in the law which lead to "dollar savings" and "discount rates." In other words, can it be said that the full "merit rating" provided has been earned? To be sure some have earned part of it; but much more can be gained. Table 1 shows how this has been effected by the Akron water utility during the past eight years. The table shows $29,022.94 saved in eight years, and, to refer back to 1937, a reduction in the premium from $2.28 to $0.74 per $100 of payroll, a reduction of $1.54 or 67.5 per cent.

How the Individual Worker Benefits

The individual workman might ask: "How does this help me?" It does, in a very real manner, as follows:

First, it provides the funds to support a real, live safety program.

Second, a real live, safety program will inevitably reduce accidents through the application of well-proven sound, safety measures.

Third, reduction in accidents means fewer employees who will be called upon to suffer and to lose time.

Fourth, less lost time through fewer accidents means greater production, higher payroll, increased efficiency.

In short, everybody wins, for "the accident you prevent may be your own." And, again, fewer accidents reduce compensation premiums, to provide funds to inaugurate safety programs to prevent accidents. Money thus saved and "plowed back" into a safety program helps the employer, the employee, and the utility—another evidence of a chain reaction.

Is This an Undue Burden on Management?

Does not this place an undue burden on utility management? Not at all. Some lazy utility managers may think so, but since a good safety program is part and parcel of the overall problem of conducting a successful business, it will force recognition and acceptance upon any manager. It is just as impor-

TABLE 1

Comparison of Workmen's Compensation Premium Rates of All Ohio Cities and City of Akron

Year	Water Dept. Payroll, $	All Cities Base Rate, $ per $100	Premiums at City Base Rate, $	Akron Rate, $ per $100	Akron* Premium, $	Savings to Water Dept., $	Savings, % of Base
1947	491,706	0.65	3,196.09	0.59	2,901.07	295.02	9.2
1948	574,347	0.65	3,733.26	0.53	3,044.04	689.22	18.5
1949	635,335	0.65	4,129.68	0.50	3,176.67	953.01	23.1
1950	660,992	0.80	5,287.94	0.54	3,569.36	1,718.58	32.5
1951	738,433	0.94	6,941.27	0.51	3,766.01	3,175.26	45.7
1952	817,260	1.03	8,417.78	0.55	4,494.93	3,922.85	46.6
1953	924,558	1.55	14,330.65	0.74	6,841.73	7,488.92	52.3
1954	962,507	1.86	17,902.63	0.74	7,122.55	10,780.08	60.2
Total	5,805,138	.....	63,939.30	.....	34,916.36	29,022.94	45.4

* Water Department.

tant as selecting a proper commodity, a suitable building site, or the purchase of necessary tools, equipment and materials.

Therefore, a positive demand on the part of the chief executive of a water utility will, of course, be translated into an equally active interest on the part of supervisors through the usual channels of training, upgrading, persuasion, and other conventional devices by which executive orders get carried out. The specific procedures and materials for creating and maintaining interest in safety are available from the National Safety Council, insurance companies, the U. S. Department of Labor, the American Water Works Association, and other authoritative sources.

Safety is a plan for living—a philosophy of life, whereby the well-ordered individual adds to the sum-total of a satisfying life. The safe workman considers in his approach to a job of work, not only proper tools, necessary equipment and selected materials, but also a *safe* plan for its execution. A job cannot be accomplished properly unless it is concluded safely. Safety-mindedness is a product of self-discipline, good instruction, proper direction and continuous exemplification.

Does it follow that a safety program is good business? Obviously. If safety programs were not good business, the wealthiest, most powerful, most competitive water utilities in the world would not be increasingly supporting them with larger and larger budgets for the setting up of safety departments, the hiring of trained personnel, and the insistence upon safe procedures in personnel processes.

Safety programs are even more than good business: they are good employee relations, good public relations, and good protection against legislative control. A utility which has its house in order need not fear the approach of authority to make it so.

Yes, SAFETY does produce dollar savings, and dollar savings are put to work — to the greater safety and greater benefit of employee and employer alike.

Alert Today — Alive Tomorrow!

I. SAFETY IN SEWERS

1. Avoid *all* open lights and sparks around manholes and in sewers. Use explosion-proof safety electric lights.
2. Employ a safety belt when entering any manhole or pit deeper than *10* feet and have two men stand by.
3. Test deep manholes or pits for combustible gases, oxygen deficiency, carbon monoxide and hydrogen sulphide. Observe any foreign odor or irritation to the eyes.
4. If any of the tests in (3) is positive, thoroughly ventilate structure with compressed air or a portable blower and repeat tests.
5. In emergencies, when a known hazard exists or tests in (3) have not been made, wear a hose mask or compressed air demand-type mask and avoid all sources of ignition.

II. SAFETY IN SEWAGE PUMPING STATIONS AND TREATMENT PLANTS

1. Guard against falls.
2. Handle objects safely.
3. Provide guards for openings to structures below grade and for moving parts of machinery.
4. Do not connect potable water piping with sewage or sludge pipes.
5. Where chlorine is used follow instructions in "Chlorine Manual" available from Chlorine Institute, 50 East 41st St., New York 17, New York.
6. Keep sludge digesters *full* when in operation and maintain sludge gas collection system under *positive* pressure. Check periodically for sludge gas leaks with combustible gas indicator.
7. Post at telephone the emergency numbers of the fire department, police, ambulance service and several doctors.

III. GENERAL PERSONAL PRECAUTIONS

1. Do not smoke in any structure where combustible gases may be present (sewers, gas collection galleries, etc.)
2. Wash hands (with hot water and soap) after work and before smoking or eating.
3. Administer prompt first-aid to *all* minor cuts or wounds.
4. Have yearly booster shots for typhoid and tetanus.
5. Be familiar with Nielson arm-lift back-pressure method of artificial respiration.
6. Employ good housekeeping.
7. Have available The Federation's Manual of Practice No. 1.

The ABC of Safety: Always Be Careful!

SEWAGE Works Safety Placard of New England Sew. & Ind. Waste Assn.

W. & S. W.—REFERENCE & DATA—1957

III. FUNCTIONAL OPERATIONS

THE FOLLOWING SECTION is devoted to the subject of functional operations and the problems and phases they include. The brief outline below sets forth the principal factors which are important to managers, superintendents and operators of water and sewage works, both large and small.

Not every aspect of these important factors can be included in one issue but other reference material on this subject will be found in previous Reference & Data Numbers.

Outline of Functional Operations

I. Pumping
- A. Reasons for pumping
  - 1. To move liquid
  - 2. To create pressure
- B. Methods of pumping
  - 1. Mechanical
    - a. Reciprocating pumps
    - b. Centrifugal pumps
  - 2. Air Lift
- C. Design of pumping systems
  - 1. According to use
  - 2. Motive power
- D. Operation
  - 1. Installation
  - 2. Procedures

II. Electricity
- A. Fundamentals
  - 1. Kinds of current
  - 2. Power
- B. Types of Motors
  - 1. Induction
  - 2. Synchronous
- C. Motor Design
  - 1. Types
  - 2. Service
  - 3. Speed
- D. Motor Installation
  - 1. Settings
  - 2. Transformers
  - 3. Relays and circuit breakers
  - 4. Switch boards
  - 5. Safe practices

III. Flow Measurement
- A. Reason for measuring flow
  - 1. Water supply
  - 2. Sewage disposal
- B. Metering Points
  - 1. Water supply
  - 2. Sewage disposal
- C. Devices for flow measurment
  - 1. Head-area meters
  - 2. Functional meters
  - 3. Displacement meters
- D. Selection of Units
  - 1. Primary units
  - 2. Secondary units
- E. Operating problems

IV. Instrumentational and Control
- A. Transmission
  - 1. Mechanical
  - 2. Electrical
  - 3. Pneumatic
- B. Receivers
  - 1. Function
  - 2. Type of chart or scale
- C. Controls
  - 1. Types
    - a. Manual
    - b. Semi-Automatic
    - c. Automatic
    - d. Pacing
  - 2. Functions
    - a. Flow control
    - b. Chemical feed control
    - c. Pump control
    - d. Level, pressure, temperature
    - e. Filter operation
- D. Selection Factors
  - 1. Primary instruments
  - 2. Secondary instruments
  - 3. Control

V. Chemical Handling and Feeding
- A. Chemicals Used
  - 1. Shipping data
  - 2. Characteristics
  - 3. Storage and Handling
  - 4. Safety
- B. Chemical Feeders
  - 1. Types
    - a. Volumetric
    - b. Gravimetric
    - c. Solution
    - d. Gas
- C. Feeding
  - 1. Water Treatment
  - 2. Sewage Treatment
- D. Control
  - 1. Analysis
  - 2. Instrumentation

VI. Coagulation
- A. Purpose
  - 1. Water Treatment
  - 2. Sewage Treatment
- B. Chemicals used
- C. Chemical reactions
- D. Control

VII. Sedimentation
- A. Mixing
  - 1. Purpose
  - 2. Time and type
- B. Settling
  - 1. Type of tank
  - 2. Time
  - 3. Sludge removal

VIII. Corrosion
- A. Mechanism
  - 1. Role of electricity
  - 2. Role of oxygen
- B. Conditions
  - 1. Water
  - 2. Sewage
- C. Prevention
  - 1. Protective coatings
  - 2. Cathodic protection
  - 3. Treatment of water

IX. Laboratory Control
- A. Purpose
- B. Equipment required
- C. Tests used

X. Maintenance
- A. Preventive
- B. Corrective

Multi-Speed Pumps for Load Changes

by H. J. MEEKER

Retired Vice President, Public Works Div., Worthington Pump Co., Harrison, N. J.

MANY PUMPING STATIONS in operation today that have an installed capacity equivalent to the flow of a good-sized river. Where large volumes of water are transported through pipelines, either downhill by gravity or pumped uphill to the point of use, the control of these flows becomes an important matter. It is necessary to provide facilities and a method for preventing damage from pressure surges that may result when the flow through a pipeline is suddenly stopped.

This is exemplified in pumping plants for water works and sewerage service, as well as in hydroelectric plants—all being subject to changes in load. So that the most efficient system can be obtained, the changes in the volume of the flow should be made as gradual as possible. To vary the water flow in the old days of steam pumps, the operator changed the engine speed at the steam throttle. When the electric age arrived, a variable-speed motor or combinations of several constant-speed units were used to meet the change in pumping loads. The synchronous motor, with its higher efficiency and improved load factor, offered many advantages. However, this type of motor could only be used in constant-speed pumping and therefore lacked flexibility.

Magnetic Drive Proves Its Value

It was evident that a pumping unit having the advantages of the synchronous motor, and with some means of varying the speed of the pump, would provide an ideal unit for regulating the flow. The magnetic drive had been developed and used for many years, in various services. To our knowledge it had been used in one instance for low-head water pumping. However, it had never been used for sewage pumping until it was installed at the Nut Island sewage treatment plant of Boston, Mass.

The problem at this plant required close regulation of the level in the suction well, as the coarse solids comminutors are located between the grit chambers and the pump suction well. For proper operation of the comminutors, a regulation of three inches plus or minus from a normal level, with a flow from 20 to 270 mgd, was needed.

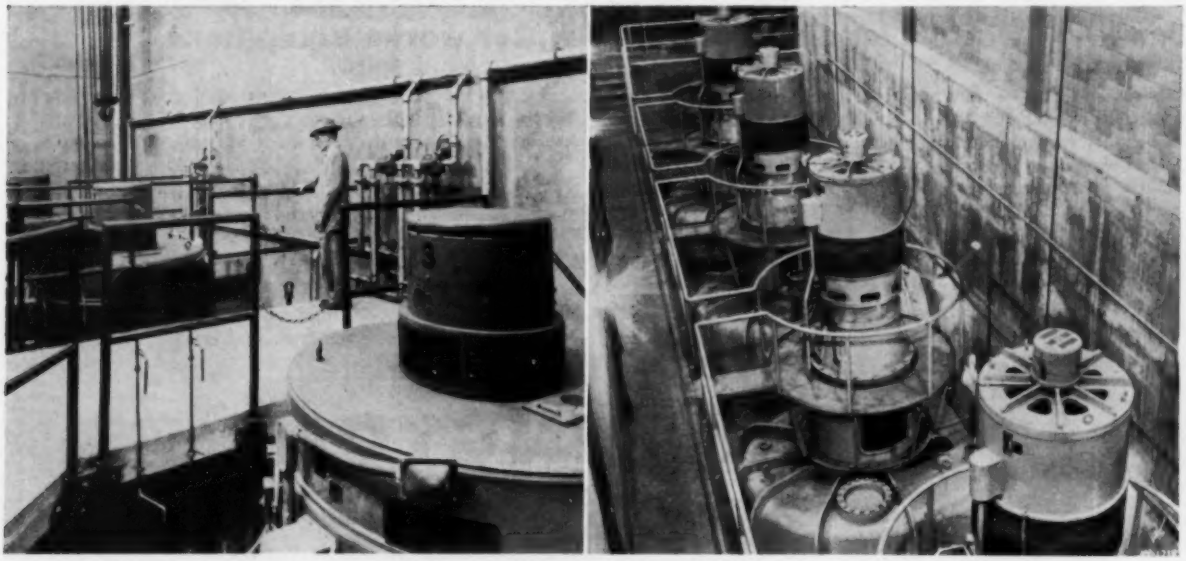
At that time no machine was available that would combine with the synchronous motor and the magnetic drive to automatically obtain the stepless regulation of pump speed for holding the suction well within the desired limits. One was developed, however, and this pumping plant has now been in successful operation for four years. Since the author described this installation in an article published in the October 1949 issue of *Water and Sewage Works*, entitled, "First Magnetic Drives for Sewage Pumps," only the fundamental design of the flow control is described here.

Flow Control Unit

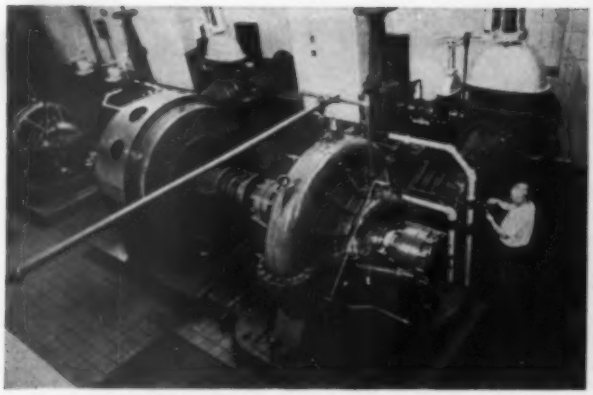
The flow control unit consists of a 14-inch diameter aluminum float which is raised or lowered by the water level in the pump suction well. It is suspended by a chain, riding on a sprocket wheel and having a counterweight on the other end. The sprocket wheel is attached to a horizontal shaft with a cam disc, rotating with the sprocket as the water level changes.

A potentiometer regulates the speed of the magnetic drive. Four of them (one for each unit) are located on shafts parallel to the main shaft of the flow control. Two potentiometers on each of the two shafts control the four pumping units. The motion of the cam shaft is transmitted to the potentiometers by a cam follower guided in the groove of the cam disc. Thus, the rotation of the disc gives a reciprocating motion to a rod hinged to the cam follower.

A rack on the rod engages two gears on the potentiometer shafts, resulting in a rotary motion of the potentiometers. This regulates the magnetic drive. Mercury switches mounted on the end of the main shaft, opposite the sprocket wheel, provide for automatic starting and stopping of the drive. They also operate indicator lights mounted on the panel board. Over-travel on the cam disc is provided to hold at maximum or minimum pump speed beyond the range

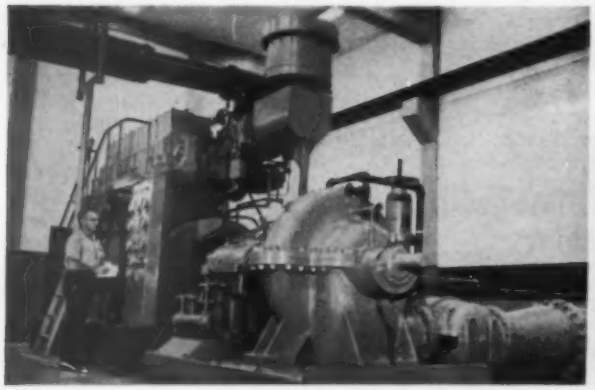


MAGNETIC DRIVES provide multi-speed sewage pumping control at St. Louis (left) and Boston (right)

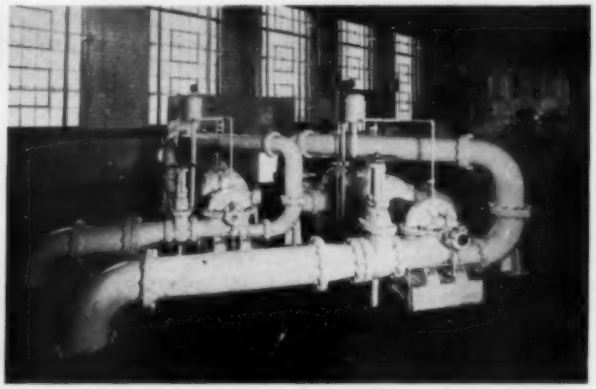


PHILADELPHIA, PA. One of ten Worthington high lift centrifugal pumps at the Torresdale Pumping Station. Capacity of this pump is 40 MGD.

NIAGARA FALLS, N. Y. Worthington high lift pumps in the Water Filtration Plant. In all, there are ten Worthington pumps, 15 to 30 MGD each.



MIAMI, FLA. One of four Worthington 15 MGD pumps driven by a Worthington diesel engine at the new Alexander Orr, Jr., Water Treatment Plant.



SHARON, PA. Two Worthington two-stage centrifugal pumps at the Sharon Valley Water Company. Capacity of the units is 2 MGD and 4 MGD each.

Reliability proved a thousand times a day

You benefit 3 ways when you deal with Worthington— world's leading builder of water works equipment

High output and low costs. Literally thousands of municipalities from the smallest to the largest have found that they get high volume output and low operating costs when they install water works equipment by Worthington. Every day, the reliability of this equipment is thoroughly proved in installations like those pictured here.

An unbiased recommendation. Because Worthington makes all types of pumps and drives, you get the advantage of an equipment recommendation based on a broad look at all available ways of doing the job. Trained specialists will help you analyze your requirements and select the proper equipment.

Unit responsibility. You do business with one company—eliminating delays and inconvenience that can occur when you are forced to co-ordinate the efforts of several suppliers. Unit responsibility by Worthington saves you time and money.

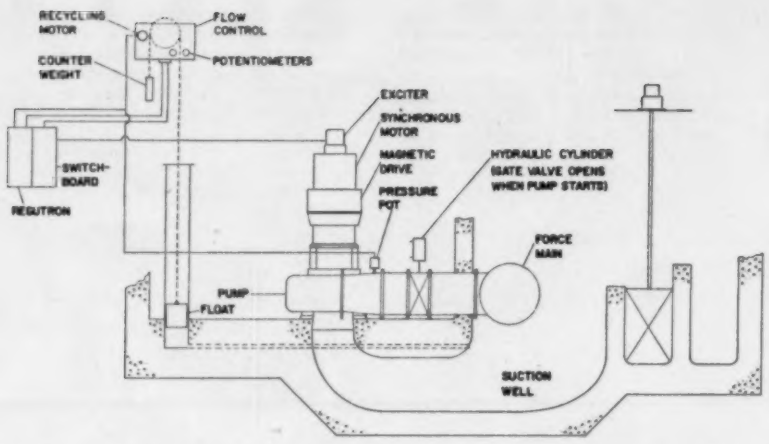
Some of the water works equipment built by Worthington include: horizontal and vertical centrifugal pumps; vertical turbine pumps; diesel, gas and dual fuel engines; steam turbines; speed increasing gears; and water meters.

For more information on any of these products, call your nearest Worthington District Office, or write Section W66, Worthington Corporation, Public Works Department, Harrison, N. J. In Canada: Worthington (Canada) 1955, Ltd., Toronto, Ont.

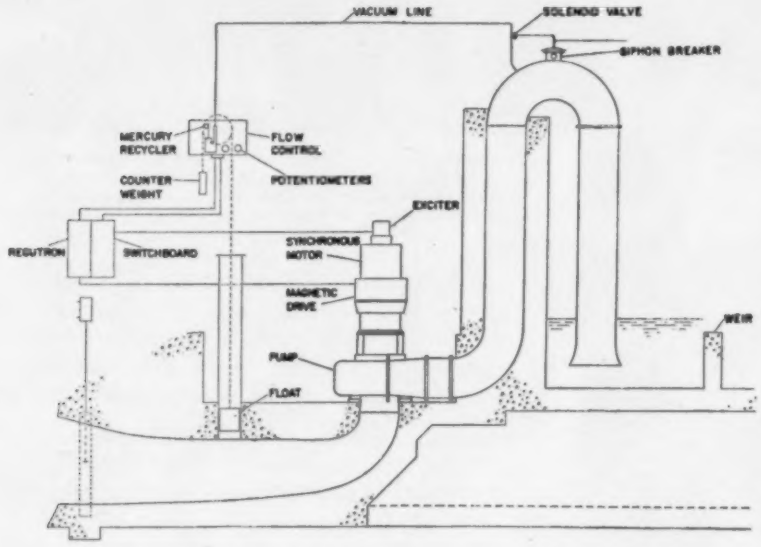
W.6.6

WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY



RECYCLING flow control actuated from pressure on discharge when pumping through force main



RECYCLING flow control actuated from vacuum at siphon invert

TABLE I
Data on Pumping Units Described

Station	Units		Capacity, mgd*		Head Range, ft	Motor Size, hp
	No.	Size, in.	Min.	Max.		
Boston, Mass. (Nut Island)	4	48	20	90	8-10.3	200
Camden, N. J.	4	30	15	30	40-41	300
St. Louis, Mo. (River des Peres):						
Station No. 1	3	36	32.4	77.7	12-37	350
Station No. 2	4	42	13	53.8	53-66	700
New Rochelle, N. Y.	4	16	1.39	10.0	25-34.5	75

*Each unit.

of the speed variation. This is necessary to allow the level in the suction well to temporarily rise or fall beyond the operating range. In this way, the contact switches for starting or stopping successive units will function properly.

Unit Improvements Provide For Recycling

Since the installation of this unit at Nut Island, the general appearance of the flow control has been improved and new features included that provide for recycling and other special conditions. It is, of course, not always practical to hold the suction well level constant (or practically so), as is done at Nut Island.

Variations in the design of the cam disc to provide for lesser or greater speed variation and the amount of under- and over-travel, will meet some conditions without provision for recycling. Where conditions require wide variations in the suction well level, or the head against the pump discharge varies, recycling of the flow control is necessary.

Recycling is accomplished by changing the relation between the sprocket wheel on the main shaft and the position of the potentiometers operating the magnetic drive. The nature of the hydraulic problem determines how the recycling will be done. In some cases, the torque initiating the motion of the potentiometers is obtained from the float in the suction well; in others, by the variation in discharge pressure.

Other Installations of Flow Control

Other installations of the flow control unit have more recently been made in the sewage pumping stations of Camden, N. J., New Rochelle, N. Y., and St. Louis, Mo. Because the hydraulic problems in each case are different, the solutions are interesting and should be noted.

At the Camden plant there are no comminutors discharging into the pump suction well. The well is connected to a long sewer of 7-foot diameter. There are four pumping units, three of which are for maximum flow (similar to the Nut Island plant). The change in suction well level is 4.5 feet from minimum to maximum flow. Each unit operates over a range of 1.50 feet before recycling begins. The suction well level is at maximum at full flow with the three units in operation, and at the lowest level when only one unit is in service.

As the pumps at Camden and Nut Island discharge to sewage treatment plants at a fairly constant discharge head, the flow controls used are similar except for the recycling feature in the Camden control. This is accomplished by a 1/12-hp reversing motor mounted on the control. It changes the relative position of the sprocket wheel with the potentiometers at each 1.5-foot increment of suction well level.

When the maximum capacity of one unit is reached, the speed is immediately reduced, the second unit is started, and the load becomes equally divided between the two. Similar division of the load occurs when the third is placed in service. Thus, stepless control of the flow over the entire

range prevents any sudden change in the rate of flow to the treatment plant.

Methods for Providing Recycling

To date the following three methods have been developed to provide recycling of the flow control; others may prove practical if the hydraulic problem warrants:

1. A reversing motor that changes the relative position of the float in the suction well with the potentiometers, automatically actuating the magnetic drive to obtain changes in speed.
2. A pressure pot with switch on the discharge side of the pump, which acts as a pilot to the recycling motor, independent of the suction well level.
3. A vacuum line from invert of discharge siphon and a mercury tube, providing power to operate the potentiometers for the magnetic drive. This device also operates independently of the suction well level.

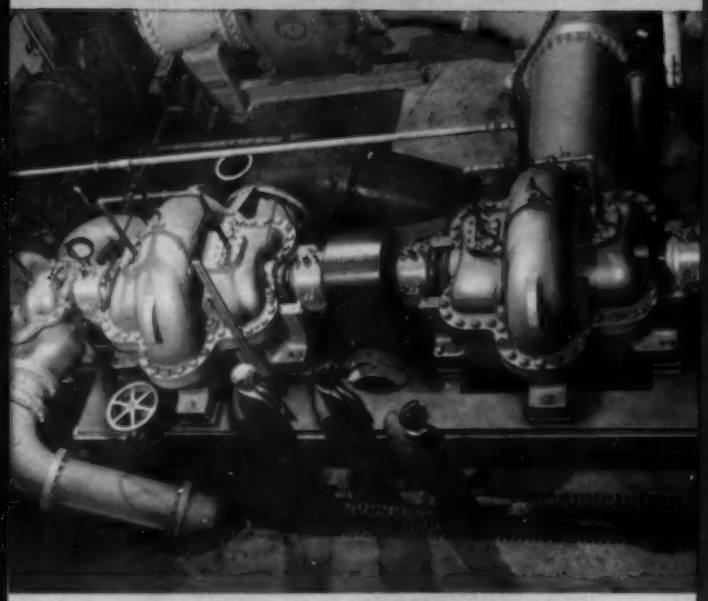
Advantages of Flow Control

The advantages of automatic control for the operation of pumping plants are:

1. Reduced labor costs.
2. Ability to operate a plant having a wide variation at the rate of flow or pumping head at maximum efficiency point with one or all units in service with a minimum of over- or under-pumping.
3. Avoids sudden changes in rate of flow to sewage treatment plant.
4. Eliminates frequent on-and-off operation of plant, with resultant power inrush at starting. Another factor toward reduction in cost of power.
5. Maintains proper sedimentation of solids in sewage treatment plants.

The pertinent data on the pumping units at the installations mentioned in this article are given in Table 1.

ALLIS-CHALMERS



Milwaukee added 40 mgd to its pumping capacity by installing this 60-mgd Allis-Chalmers centrifugal unit in the space formerly occupied by one 20-mgd pumping engine. This new unit is driven by an Allis-Chalmers 3700-hp steam turbine and is also supplied with an A-C condenser.

Allis-Chalmers can supply a major percentage of the equipment needed for sewage plants, water works, municipal power plants, street and highway construction, and other public works. See the three following pages for further information on A-C equipment.

The record of Allis-Chalmers in building centrifugal pumps speaks for itself. Of thousands built, no A-C centrifugal pump has ever failed to meet its guaranteed efficiency. This means that when you specify Allis-Chalmers you are getting exactly what you intended to buy . . . exactly what you need.

Hundreds of cities . . . large and small . . . are already profiting from the efficiencies of Allis-Chalmers pumps. The range of types and capacities of A-C pumps will meet the needs of any city. There are special pumps for water supply, fire protection, sewage, and drainage. Sizes range from small compact units handling only a few gallons per minute to huge 72-inch pumps capable of handling 300,000 gpm.

Also worth while remembering is that you can get the entire pumping unit from Allis-Chalmers . . . for this company builds motors of every type, for operating every size of pump. You can also get the proper A-C starter for controlling the motor.

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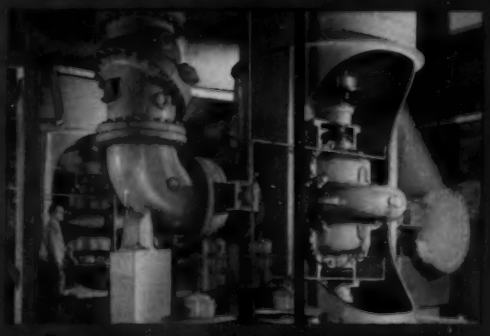
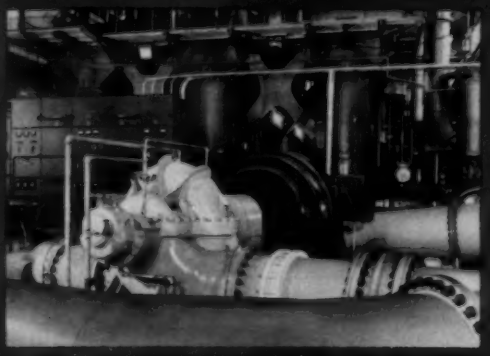
Builds

WORLD'S WIDEST RANGE OF PUBLIC WORKS EQUIPMENT





How to make

SEWAGE DISPOSAL

PAY!

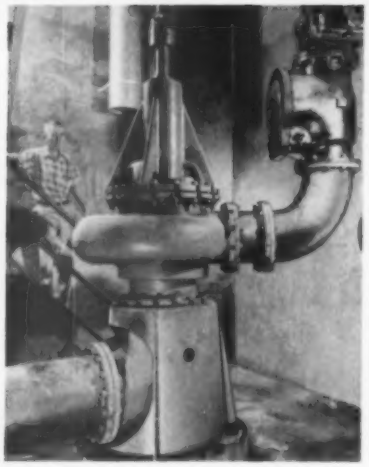
By-products can help pay part of sewage system expansion costs. Here's how...

The flow sheet at the right shows two modern treatment methods that use by-products to help meet expansion costs.

- Some cities, through the sale of fertilizer, are recovering a large percentage of the cost of operation.
- Other cities are using digester gas to supply most of the sewage power and light needs.
- Many industrial sewage plants are paying their way with similar improvements.
- The increasing use of home garbage disposal units is aiding many municipal plants to increase their by-product value.

Get Help on Your Problem

Allis-Chalmers, builders of the world's widest range of public works equipment, can help you analyze your problem and select the proper equipment for your particular needs. For complete information on any of the Allis-Chalmers items shown here . . . call your nearby Allis-Chalmers District Office or write Allis-Chalmers, Milwaukee 1, Wisconsin.



Allis-Chalmers 16 by 14-in. vertical sewage pump on combined storm and sanitary sewer main.

Some A-C Products for Sewage Works

CENTRIFUGAL PUMPS—Vertical or horizontal, for sewage and activated sludge.

BLOWERS—For sewage aeration.

ROTARY VACUUM PUMPS—For use with vacuum filters in dewatering sludge.

ROTARY COMPRESSORS—For compressing digester gas.

DRYERS—For sludge dewatering.

VIBRATING SCREENS — For removing solids from liquids; also in fertilizer manufacture.

SIFTERS—For grading fertilizer.

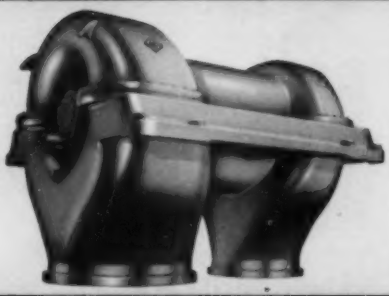
ROLLER MILLS—For grinding fertilizer.

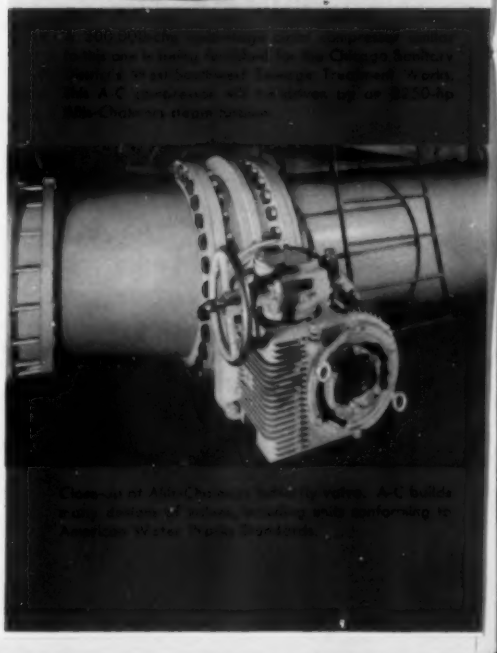
V-BELT DRIVES—Constant and adjustable speed.

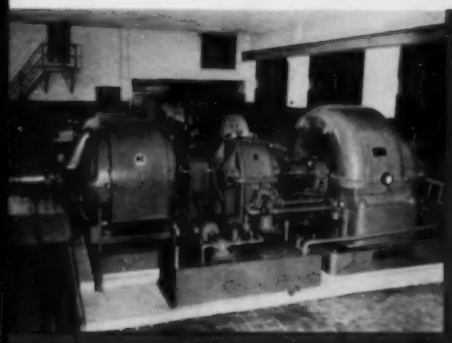
MOTORS AND CONTROL—For all drives over 1 hp.

POWER EQUIPMENT—Steam turbines, condensers, pumps, water conditioning.

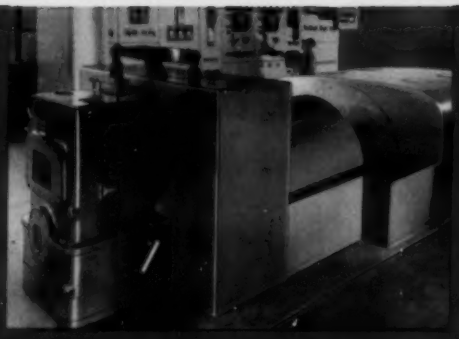
ELECTRICAL EQUIPMENT—Transformers, switchgear, circuit breakers, unit substations, generators, voltage regulators.



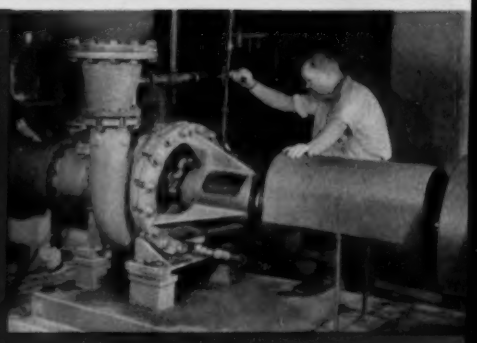




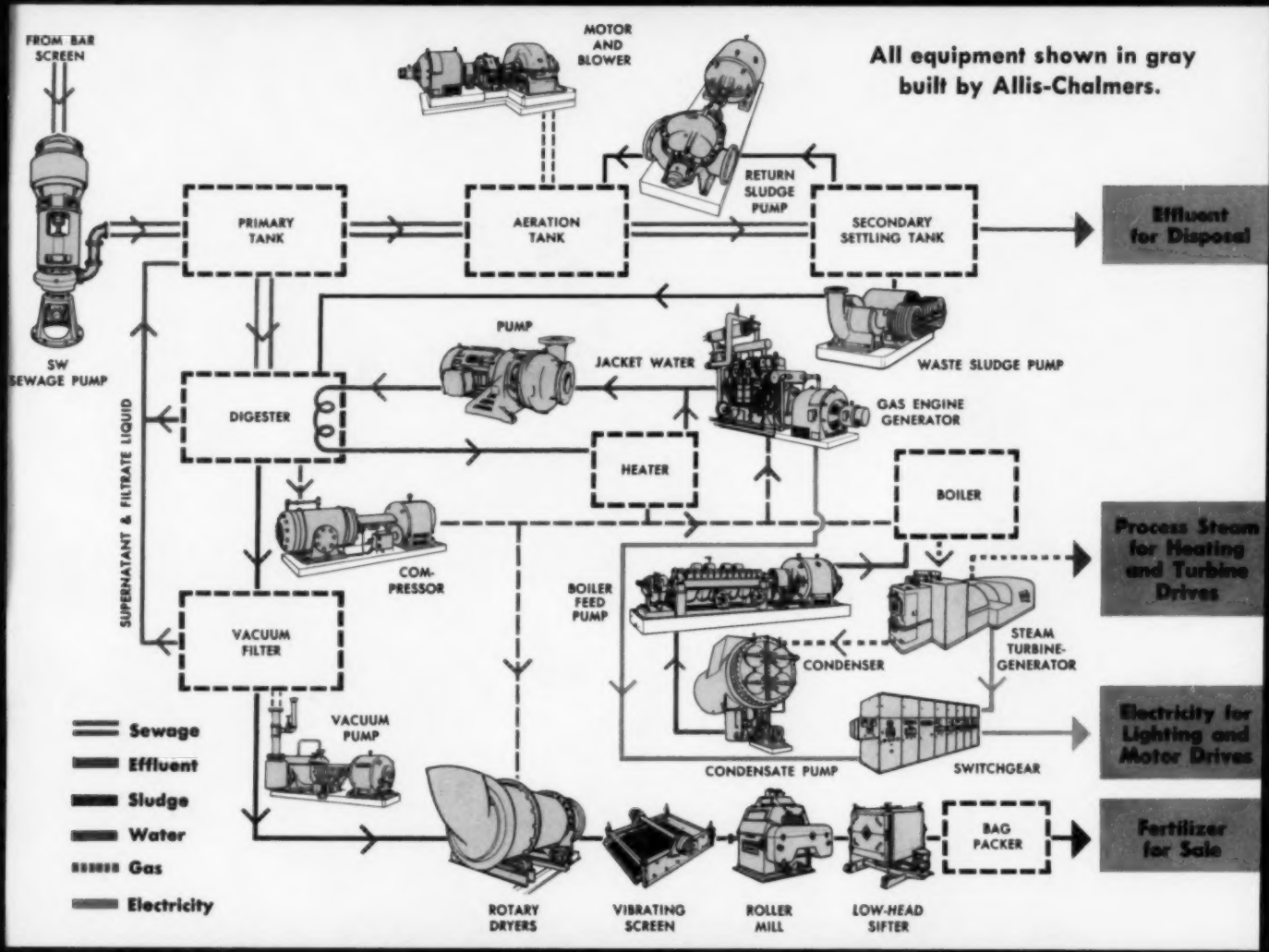
Three A-C blower units, 27,000 cfm, 10,000 cfm, 15,000 cfm.



A-C 2500-kw, 3600-rpm WA-Series steam turbine-generator unit with A-C switchgear in background.



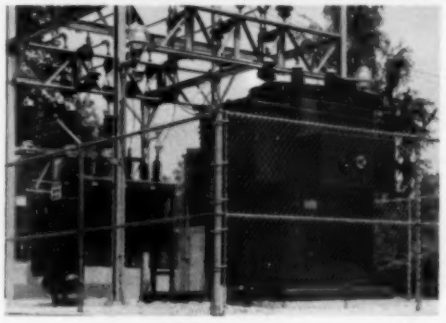
A-C sewage pumps have wide impeller openings, rounded impeller inlets to pass solids freely.



ALLIS-CHALMERS

← Rear view of 3000-kva, 4160-2400-volt unit substation with both incoming line section and distribution feeder section consisting of metal-clad switchgear.

Allis-Chalmers outdoor substation protects and controls the electrical power supply for a pumping station.



Electric Power Equipment

MOTOR CONTROLS: Dependable start-stop control for all sewage processing apparatus, in both single and grouped units. Simplified installation requires only connection to leads for operation. Expandable design permits easy addition of more cubicles when required.

Allis-Chalmers can supply a major percentage of all power generation, and electrical control and distribution equipment for public works. Included in the power generation line are steam turbine generator units, surface condensers, condenser and boiler feed pumps, water conditioning service and equipment.

The range of electrical products includes all types and sizes of motors from 1 hp to 100,000 hp and up, and starters or control to suit every application.

Allis-Chalmers indoor and outdoor high and low voltage switchgear provides maximum protection and flexible control of power distribution circuits. All units are metal enclosed, factory built, so they need only be bolted in place and lines connected. Switchboards are custom built to fill your needs.

A-C builds a complete line of power and distribution transformers. Most sizes can be cooled with either oil or *Chlorextol* non-inflammable liquid, or they can be of the air-cooled type.

Load center, single circuit and multi-circuit unit substations are built in standard ratings to meet every application. They are completely factory built and can be installed adjacent to equipment being served.

Chlorextol is an Allis-Chalmers trademark.

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It Pays to Replace an Old Pump

When the cost of operating an old pump exceeds the cost of a modern replacement

by C. E. CROMWELL

DeLaval Steam Turbine Co., Trenton, N. J.

DIGGING into the economics of operating an old pump frequently turns up highly profitable information. Often what appears to be "satisfactory performance" may be actually blinding us to the real costs. Reducing day in and day out operating costs can very well effect savings more than sufficient to finance a modern pump and also produce savings even beyond the important power cost reduction.

A pump may still be delivering designed capacity and head despite its age. It is this fact, the seemingly satisfactory performance of the pump, that protects from closer scrutiny its reputation as an "old faithful." Gradual decreasing efficiency is not always noticeable. Nor, are power costs looked upon as excessive unless totaled up over a span of years and compared with the overall expense of investing in a new pump. Pump manufacturers have in recent years come a long way in designing more efficient units to reduce overall operating costs.

Consider the Last Quarter Century of Progress

Consider a motor driven pump built in 1928 to handle 2,500 gpm against 150′ total head. When originally built, it had an efficiency of 78% requiring an input of 121 bhp. Due to wear and tear, and if no revolving parts have been replaced, it could be expected that the pump in 1953 would have an efficiency of about 74%, and would require 128 bhp to deliver the designed capacity and head. Note the moderate 4% loss in efficiency—apparently nothing to get excited about.

A modern 1954 pump for these same conditions could be expected to have an initial efficiency of 86%, requiring 110 bhp. This 12% efficiency difference represents a possible saving of 18 bhp. Based on a power cost of 1c per kwh. savings in power cost for one year (8760 operating hours) is $1176.00.

Application of the $1176 Annual Savings to Financing a New Pump

The cost of a new pump or complete unit, and the time it would take to pay for it from the operating-savings gained over old existing pump are shown here. The following figures are based on 1c per kwh, or $.00746 per hp. (Additional costs for freightage and for changing foundation and piping must, of course, be included in arriving at the total cost figure.)

New Pump Unit Costs

Price (estimated) of new pump, base, coupling	$1238
Price (estimated) of 125-hp 440-v 1750-rpm motor	1390
Price (estimated) of reduced voltage starter	1170
Total cost of new pump, motor, starter	$3798

	Hours of Operation per Year		
	8760*	6500	4000
Savings will pay for pump, base and coupling in.	13 mos.	17 mos.	28 mos.
Savings will pay for complete unit in	39 mos.	52 mos.	84 mos.

*Continuous operation of single unit.

Even if renewal parts for the 1928 pump could restore its original efficiency of 78%, it still requires 11 hp more than the new pump. Based on 8760-hr. operation per year, power cost of old unit is still $719 more.

Depending on how out of date the pump parts are, they might be relatively expensive, compared with the cost of a modern pump.

A Surprise to Some: Perhaps to Many

If the amount saved each year on power cost were set aside to accumulate interest, the total will then represent an amount that will pay for all or part of the cost of a new unit. If the pump owner's practice is to consider relatively long term write-offs, these saving may well be sufficient to pay for the new unit and also for other additional capital expenditures.

A municipality figures in terms of bond issues of 15 years or more and even at presently favorable interest rates of 3% a small annual saving, based on the preceding example, soon pays for the original investment. In fact, many cases would show that by the end of a 15 year term such savings would represent the write-off of a much larger capital expenditure. Take the $1176 saved on power cost with a new pump, as shown: If, for a municipality, this amount were set aside to accumulate interest at 3% compounded annually for 15 years, it may surprise some to find that a capital investment of $21,871 could be written off.

Some operators of central-station power plants believe that in a new station a unit that pays for itself in 8 to 10 years is a good investment. When replacing old equipment, the expected life of the plant may reduce the length of write-off that can be considered. This premise must be considered throughout industry, regardless of the products.

Chemical companies or oil refineries prefer to write off investments in 3 to 4 years, or possibly 2 years. A chemical company capitalizing the savings at 4% for four years could only write off an investment of $4994.00. Even so, the practice of rapid write off is followed in general.

Calculating Savings

Calculation of power cost savings and capitalization amounts can be made quickly by using the accompanying chart. First compute the horsepower savings and multiply the results by yearly hours of operation. This chart can be used for quick approximations and can be read within about 2% accuracy.

The diagonal lines represent "horsepower savings." The abcissa shows "hours per year" of operation. Reading vertically up the "hours per year" to the "horsepower savings," to the left ordinate is the "annual savings" in power cost, and to the right ordinate is the "capitalization amount." Shown are 3 right hand ordinates, each for different interest rates and terms of years.

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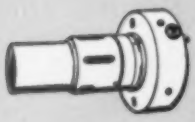

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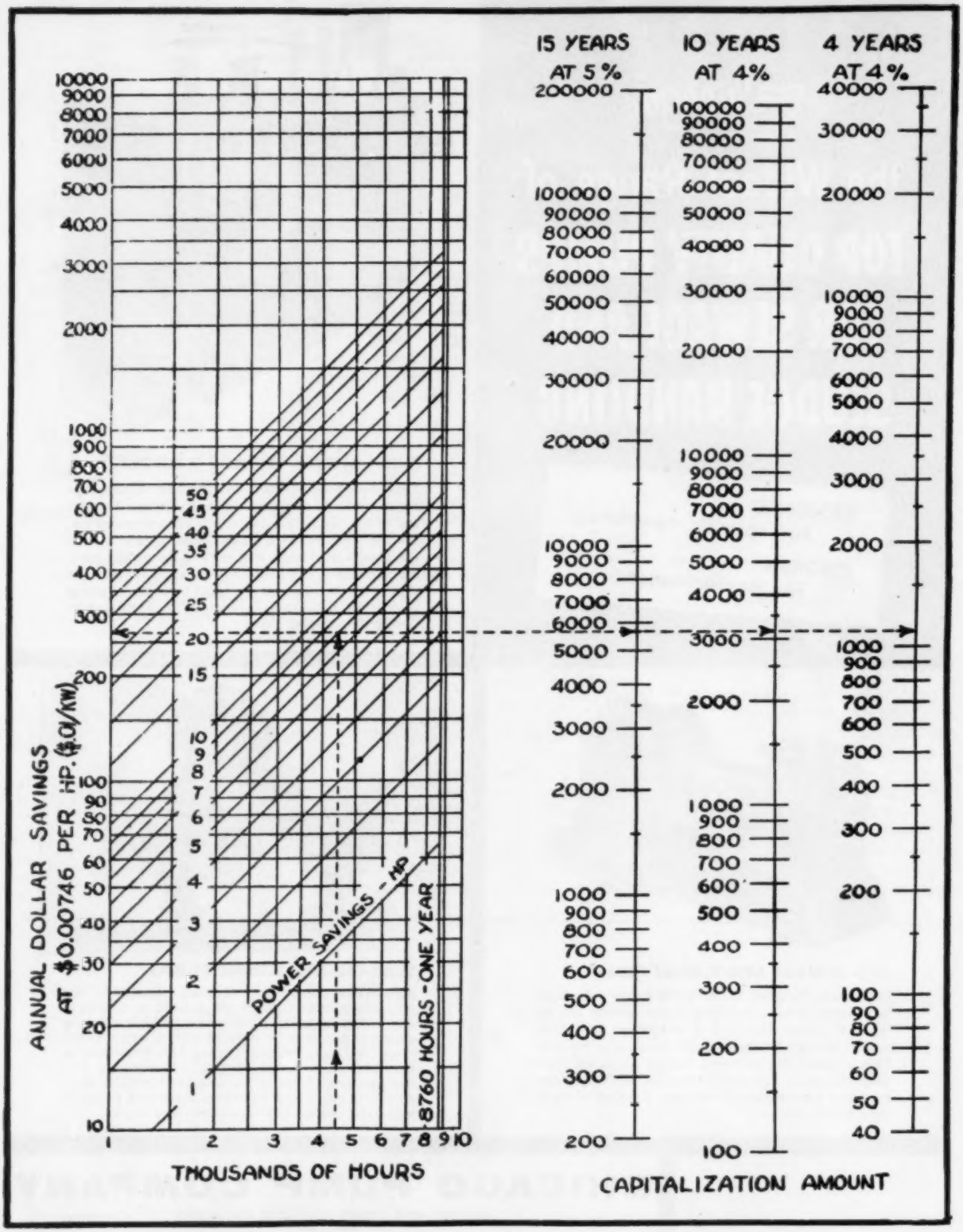
15 YEARS AT 5%
10 YEARS AT 4%
4 YEARS AT 4%
ANNUAL DOLLAR SAVINGS AT $0.00746 PER HP. ($Q/KW)
POWER SAVINGS - HP
8760 HOURS - ONE YEAR
THOUSANDS OF HOURS
CAPITALIZATION AMOUNT

CHART—For calculating power cost savings and capitalization amounts.

Compute horsepower savings and multiply by hours per year.

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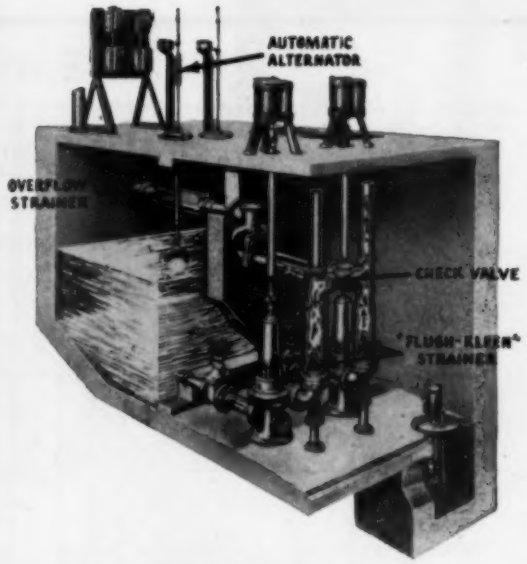

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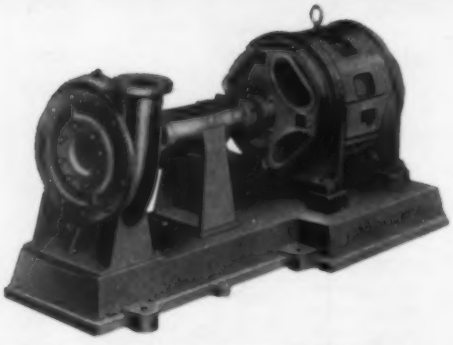

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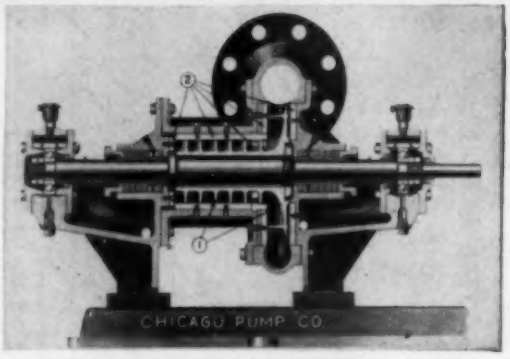

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TABLE 1*

Years	% Interest Rate/Annum, Compounded Annually				
	2	3	4	5	6
2	.49505	.49261	.49020	.48780	.48544
3	.32675	.32353	.32035	.31721	.31411
4	.24262	.23903	.23549	.23201	.22859
6	.15853	.15460	.15076	.14702	.14336
8	.11651	.11246	.10853	.10472	.10104
10	.09133	.08723	.08329	.07950	.07587
12	.07456	.07046	.06655	.06283	.05928
15	.06260	.05377	.04994	.04634	.04296

*Annual Savings divided by factors in table equals sum including interest accumulated for number of years and interest rate selected.

The chart is based on cost of power at $.01 per KW. If in a particular locality power cost is more or less, simply multiply answer from the chart by the ratio to actual cost; i.e., if the cost is 12 mils per KW, multiply by 1.2; if the cost is 9 mils per KW, multiply by 0.9.

Examples

The following examples are taken from records to show what improvements in efficiency have been made and the savings and capitalization amounts are taken from the attached chart.

1. Service Water Pump. Consider a pump installed in 1926 having an efficiency of 70% and an input of 28.9 bhp. A modern pump for the same conditions (400 gpm, 200 ft. total head) has an efficiency of 79% and an input of 25.6 bhp. This is a 3.3 bhp saving. Annual saving if service water pump runs 6000 hours per year is $150. Capitalized in 4 years at 4% interest the total amount is $630. The estimated price of a new pump for these operating conditions is $438.
2. Boiler Feed Pump. 400 gpm, 650 total head at 220 F.

year 1930, efficiency 63%,	99.5 bhp
year 1953, efficiency 69%,	91.0 bhp
saving of	8.5 bhp

Annual saving if pump operated 8760 hours per year is $560. Annual savings capitalized in 10 years at 4% represents a total of $6700. Estimated cost of new pump is $1101.

3. Water Works Pump. 15 mgd (10,400 gpm), total head—200 ft.

year 1926, efficiency 84%,	625 bhp
year 1953, efficiency 89%,	590 bhp
saving of	35 bhp

Annual saving if pump operated 5000 hours per year is $1300. Annual savings capitalized in 15 years at 3%, represents a neat total of $24,177. Estimated price of new pump is only $4054.

When accurate calculations are required for formal presentation, annual savings are obtained by multiplying horsepower savings by yearly hours of operation by cost per horsepower hour. (kwh cost x 0.746). The annual savings divided by a factor, based on terms of years of interest rate will give the capitalization amount. Table 1 lists these factors for various terms and interest rates. These can also be used for terms other than those shown on the chart.

Undoubtedly, most plant engineers in industry and municipalities realize that the wasted costs of operating old equipment could very well represent the purchase price of new equipment. But management officials must be shown why the purchase of modern equipment is a wiser investment than the continuing costs of operating old equipment.

If power and depreciation should be negligible factors (seldom the case) there are still repair costs of some kind to consider. Obsolete parts are not only more expensive but require extended delivery time. Should production losses occur because of the delay in obtaining obsolete renewal parts, the losses are chargeable to the old pump. The cost of modern renewal parts, for which patterns are available and the parts are in stock, represent very tangible savings when compared with the cost of obsolete parts. Actually, sometimes a modern pump can be purchased at prices equal to or even less than the cost of extensive renewal parts for an old pump.

The chart and examples shown here should help engineers and managers or other officials gain a graphic insight into economics of pump depreciation, deterioration and obsolescence. They will also show how the higher operating costs entailed by these three factors could be converted into appreciable yearly savings to make modernization pay its own way.

Pump Motor Starting Problems

by M. C. BOGGIS and E. O. POTTHOFF
Sewage and Water Works Application Engineers, General Electric Co., Schenectady, N. Y.

THE MAJORITY of pump motor applications in water and sewage plants do not involve a starting problem. Nevertheless, in many installations the torque requirements of the pump and the inrush limitations placed on the motor are such that careful investigation of the starting method is warranted to determine if satisfactory starting will be obtained. Typical of a problematical application might be a water booster station, likely to be located in a residential area and supplied with power from a residential feeder with attendant strict requirements to minimize voltage disturbance.

An investigation to determine the ability of a motor to break away the pump from standstill and accelerate to running speed should include consideration of motor and pump characteristics, types of starting equipment, and effects on the power system.

The proper selection of motor torques and starting method for a given application may involve a compromise between established load torques and inrush limitations. Pump starting torques, in most cases, are rigidly fixed for a given pump type, which in turn was selected to accomplish a specific hydraulic job. As will be shown, pump starting torques must not be arbitrarily considered inconsequential, because considerable variation in starting torques exists between different types of pumps and starting under different hydraulic conditions.

Limitations on starting inrush may be placed by a power company or forced by local plant conditions. The latter is exemplified in the case of a station served by a "soft" power supply which would experience severe voltage dips when motors are started unless a reduced inrush starting method were used. The adverse effects of such voltage dips will be discussed later.

Briefly, the job of resolving a pump motor starting problem is covered by four points, as follows:

1. Determine specifically which pump starting characteristic is applicable. (Typical characteristic curves should not be used except on a preliminary basis.)
2. Determine if any starting current inrush limitations apply.
3. If a squirrel cage induction motor is best suited to the application, determine if it will accelerate the load while meeting any required current inrush limitation.
4. If chosen for other reasons, determine proper synchronous motor torque values or wound-rotor induction motor starting characteristics.

In this article characteristics of the following motors and pumps will be discussed:

1. Induction motors through 500 hp, 720 to 1,800 rpm.
2. Synchronous motors 200 to 3,000 hp, 200 to 1,800 rpm, 1.0 power factor.
3. Centrifugal and axial flow pumps under various discharge arrangements and conditions.

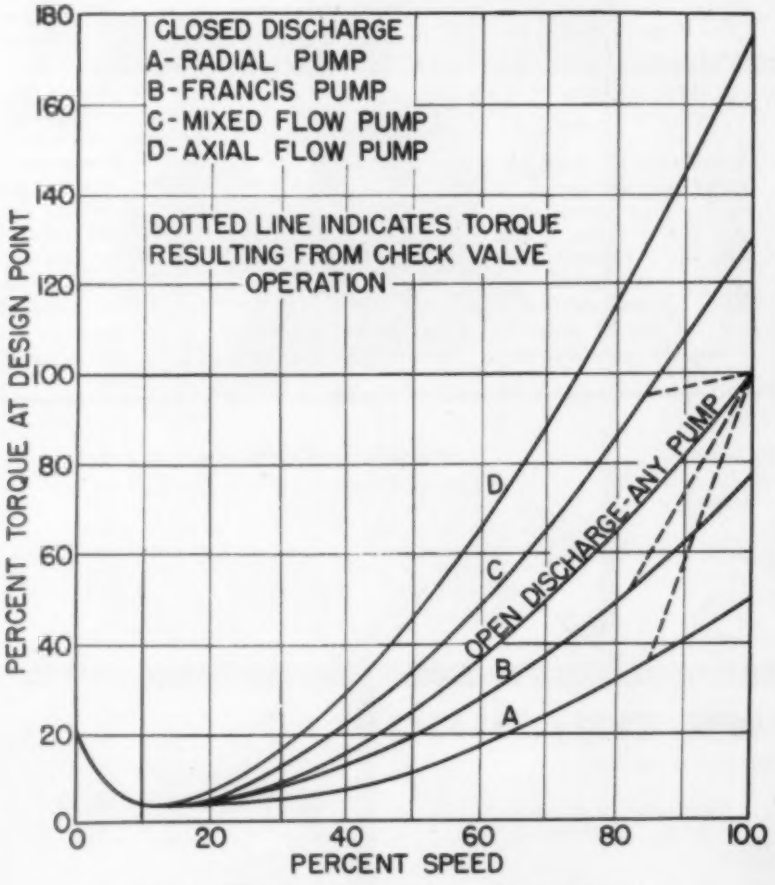


Fig. 1.—PUMP starting speed-torque characteristics

Pump Starting Characteristics

The starting speed-torque characteristic of a pump is governed by two

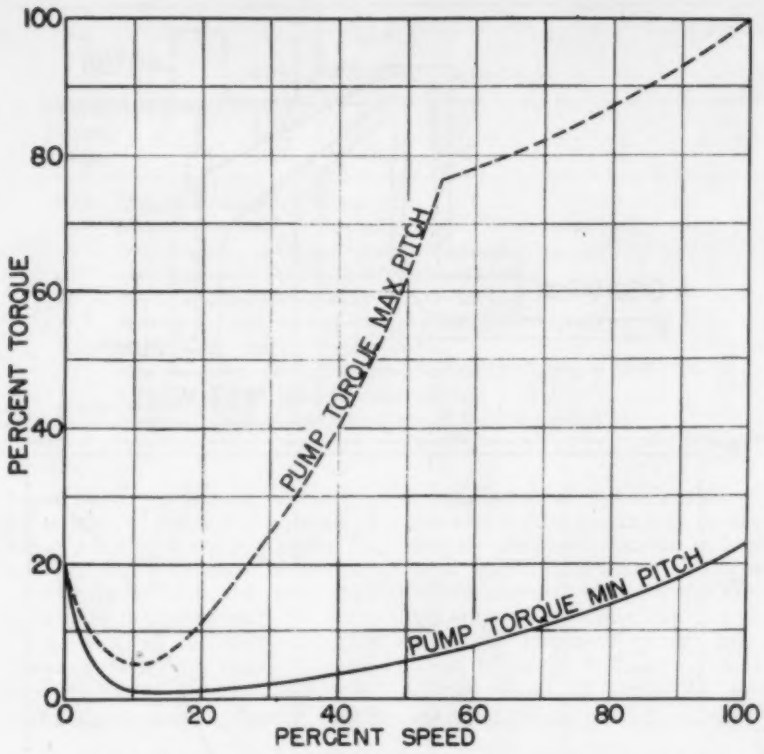


Fig. 2—TYPICAL CURVES showing starting speed-torque values of an adjustable pitch axial flow pump at both limits of impeller pitch and with tilting disc check valve in discharge line

factors—the type of pump impeller and the hydraulic conditions while starting. The latter includes an open or closed pump discharge valve, or dewatered pump casing.

Impellers can be classified on the basis of their performance and proportions regardless of actual size or their operating speed by the term "specific speed," commonly used among pump designers. This is defined as the speed at which the impeller, if reduced in size proportionately, would deliver 1 gpm at a total head of one foot. The mathematical expression for the term is:

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

In which

N = speed, in rpm;
Q = capacity, in gpm;
H = head, in ft.

The starting speed-torque curve A (Fig. 1) is representative of a radial impeller pump (specific speed approximately 500 to 3,000) under closed-discharge conditions. The open-discharge curve is also shown. Although breakaway torque is the same for either discharge condition, a large difference in torque develops as speed increases with an open-discharge torque twice that of closed-discharge at full speed. The dotted line intersecting the closed-discharge curve at approximately 85 per cent speed represents the approximate torque load when a tilting disc check valve is used which opens when the discharge pressure exceeds the line pressure.

Curve B of Fig. 1 illustrates the closed-discharge speed-torque curve for a Francis-type impeller (specific speed approximately 1,500 to 4,500). Note that the closed-discharge torque values are somewhat higher than those for the radial impeller.

Mixed-flow pumps (specific speed approximately 4,500 to 8,000) pose a difficult problem in starting because of their high torque requirements at full speed. Curve C of Fig. 1 illustrates closed-discharge starting torques. This curve represents the upper limit of torque at full speed, which may range from 100 to 130 per cent. Because closed-discharge starting is the most common usage, care must be exercised in applying synchronous motors, particularly, due to the high pull-in torques (load-torque at approximately 100 per cent speed) required.

The axial-flow or propeller pump (specific speed approximately 8,000 and above) develops pressure head by imparting a helical motion to the fluid rather than by centrifugal force. The speed-torque curve in Fig. 1 (curve D) is representative of an axial-flow fixed-vane pump closed-discharge starting characteristic. The potential starting problem under closed-discharge conditions is obvious. These pumps are also available in an adjustable-vane construction which provides a range of capacity and head conditions using a constant-speed drive. The speed-torque curves of such a pump starting against a tilting-disk valve are shown in Fig. 2, for the vanes in both limits of pitch adjustment.

A siphon discharge arrangement is commonly used in large drainage pump installations. The siphon discharge configuration is shown in Fig. 3, along with a representative starting speed-torque curve. The curve has a reverse bend at about 80 per cent speed, when water starts to spill into the drop-leg of the siphon, and then drops abruptly to normal torque at full speed when the siphon is established. If a synchronous motor were used as a drive, the load torque to be pulled into step would be roughly 115 per cent of rated full-load torque.

Occasionally pumps have been started with dry casings so that torques can be reduced to a minimum. Fig. 4 shows the low torques that can be expected with such an arrangement. To start a pump with a dry casing obviously requires a closed suction, or it must be unprimed if there is no positive suction head and a source of cooling water must be provided for shaft seals and wearing rings during starting.

Motor Starting Characteristics

NEMA design B squirrel cage induction motor characteristics are standardized as to locked-rotor torque and current and maximum torque. For water and sewage pumping, motors conforming to NEMA design B have proven to be the most satisfactory.

In a synchronous motor the amortisseur winding (starting winding) is electrically separate from the main field winding, allowing its design to be modified within limits, thus changing the starting and accelerating characteristics without affecting the running characteristics. Lower than standard inrush current is obtained at the expense of lower torques through-

out the starting range, including pull-in torques; therefore, a realistic balance must be achieved in specifying high acceleration torques and low inrush currents.

Synchronous motor torques, suitable for a specific application, may be selected by dividing the required torques by the square of the ratio of actual voltage at the motor terminals to motor-rated voltage. The most significant pump torques are those at breakaway and approximately 97 per cent speed. The calculation of actual voltage at the motor terminals must, of course, include system voltage dip and any voltage reduction as the direct result of the starting method to be used.

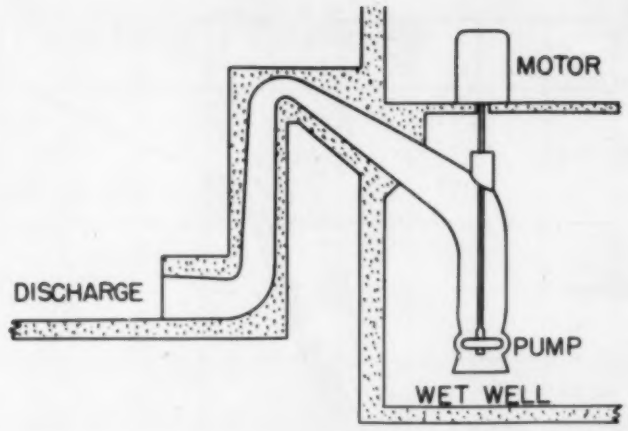
The curves in Fig. 5 may be considered typical of the starting characteristics of a low speed, vertical synchronous motor in a large rating. The torque curve shown represents air-gap torque through the starting range rather than shaft torque. This representation is desirable for vertical machines using plate-type thrust bearings, because the torque required by the thrust bearing is different at breakaway from that found during acceleration. The air-gap torque should be corrected for the actual voltage at the machine terminals and the torque required by the thrust bearing then subtracted to determine shaft torque. The thrust bearing will take approximately 25 per cent of full load torque at breakaway. The shaft torque and the air-gap torque are, for practical purposes, equal throughout the accelerating range.

In addition to breakaway torque, pull-in torque, and breakdown torque, there may be considerable significance in the actual values of motor torque at intermediate speeds, particularly in high-speed motors (1,800 and 3,600 rpm). A dip in the speed-torque curve, generally occurring at 60 to 80 per cent speed, may prevent acceleration to the desired speed. For this reason, the actual motor and pump characteristics should be used in a difficult starting problem solution rather than typical characteristics.

Wound-rotor motor starting characteristics are adjustable within wide limits of torque and current by the adjustments of external resistance in the rotor circuit. The percentages of torque and current at any particular starting step are approximately equal and are inversely proportional to per cent external resistance.

Objectives in Limiting Inrush

The need for limiting inrush on



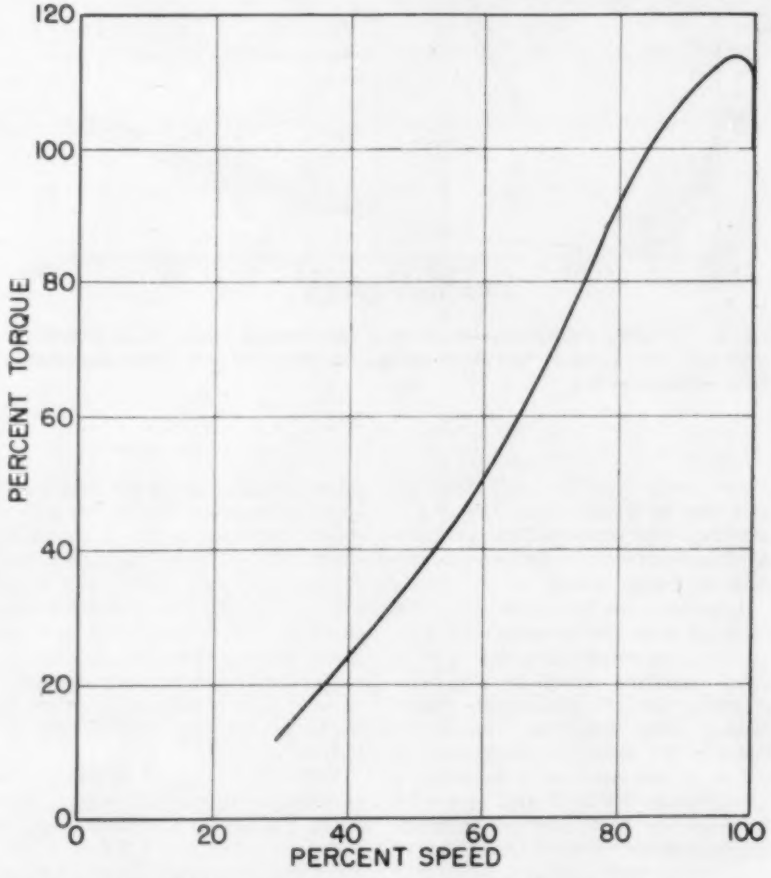


Fig. 3—STARTING characteristic of axial flow pump with siphon discharge

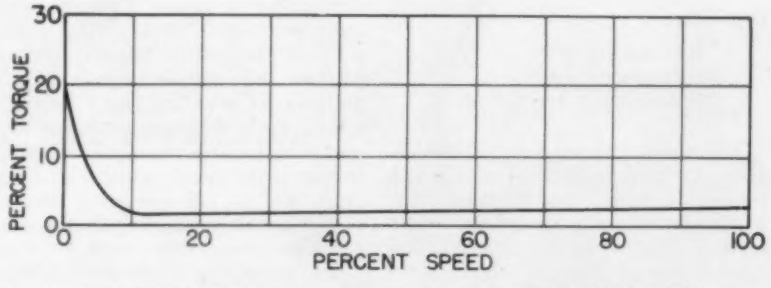


Fig. 4—REPRESENTATIVE speed-torque curve of pump started with dry casing

TABLE 1

Effects of Reduced Voltage Levels

Percent Voltage	Effects
97.5	Objectionable lighting flicker
90	Minimum operating voltage for high bay mercury lamps (sudden dip)
85	Minimum pick-up for low-voltage a-c contactors (up to NEMA size 5)
80	Minimum operating voltage for fluorescent lamps
76	115% loaded induction and synchronous motors stall
74	Minimum pick-up for high-voltage air break a-c contactor
70.5	100% loaded induction motors stall
70	Maximum drop-out for low-voltage a-c contactors (up to NEMA size 5)
67	100% loaded synchronous motors pull-out
53	Maximum drop-out for high-voltage air break a-c contactor

motor starting is determined solely by the amount of voltage disturbance allowable during a starting cycle. The interest in the voltage disturbance may be that of the local power company or of the power user.

The aims of an electrical utility company regarding voltage disturbance are, for the most part, concerned with lighting flicker. Starting inrush limitations should not be specific without reason; the power user is unnecessarily penalized costwise and, perhaps, performancewise if this occurs.

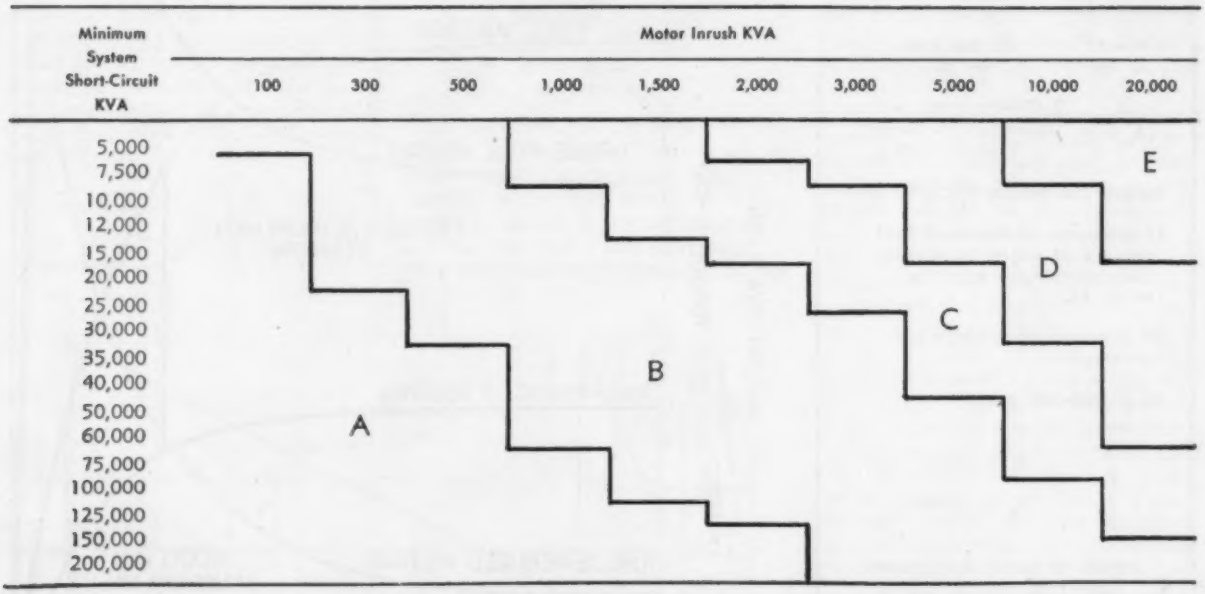
The user's objective in minimizing voltage disturbances within his plant are of a somewhat similar nature. Table 1 lists the various approximate voltage levels at which the corresponding effects will be experienced. The significance of the pick-up values for a-c contactors listed is in reduced-voltage starters where the running contactor coil must have the minimum voltage indicated to allow transfer to full voltage.

With the voltage levels listed in Table 1 as the criteria, Table 2 is an attempt to generalize on the need for reduced inrush starting on the basis of the voltage dip incurred on a system by a given motor starting power draw (kva). The suggested starting methods for the indicated areas must not, of course, be taken as the final word because of individual circumstances, but it may serve as a guide in establishing the need.

The need for reduced inrush starting equipment might also be affected by the point of measurement and calculation of the allowable inrush kva. If the interested power company specifies a kva inrush limitation measured at the line terminals of the motor starter with rated motor voltage at those terminals, the possibility of the need for special motor design or starting equipment is greater than if this measurement were made at the

TABLE 2

Need for Reduced Inrush Starting



A—Full-voltage starting should be used (voltage dip less than 1.5%).

B—Full-voltage starting acceptable from power consumer's standpoint (neglecting light flicker); power company acceptance dependent upon intervening transformers and other connected customers (voltage dip 1.5 to 10%).

C—Power company will probably insist on reduced inrush starting unless sufficient intervening impedance materially reduces voltage disturbance experienced in system (voltage dip 10 to 24%).

D—Reduced inrush starting desirable from consumer's standpoint unless no other connected load is involved (voltage dip 25 to 50%).

E—Unable to start (voltage dip greater than 50%).

primary side of the station supply transformers. The intervening impedance of the transformer acts as a starting reactor and may permit full-voltage starting equipment in borderline cases, or change the voltage tap required in a reduced-voltage starter. This is illustrated in Fig. 6.

Inrush Limitation Stipulations

Power companies may specify an inrush limitation in terms of amperes, kva, or percentage of motor full load current. An inrush limitation may be stated as an incremental value or as a maximum value drawn throughout the starting period. If, for example, a limitation of 2,000 kva is specified, the two possibilities of speed versus current are shown in Fig. 7. It is obvious that if the quantitative value of a "maximum value drawn" limitation is equal to the value of each increment in an incremental limitation, the "maximum value drawn" stipulation would be the more difficult to meet since it requires acceleration to a considerably higher speed before transition to full voltage than the incremental stipulation. An incremental starting stipulation must be further defined as to how the increments are measured; that is, are the increments cumulative at full value or are they

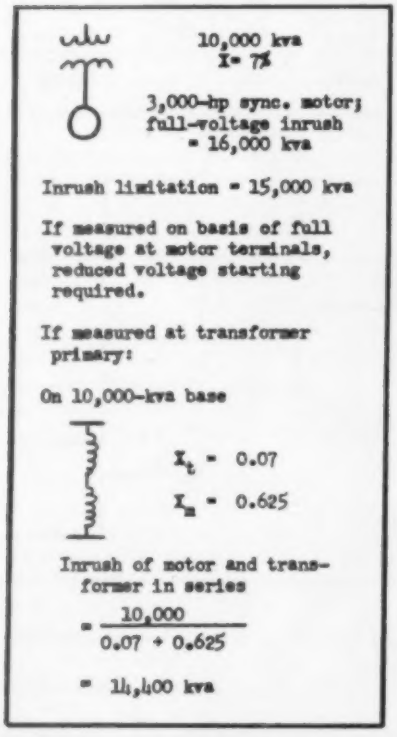

10,000 kva
X = 7%
3,000-hp sync. motor; full-voltage inrush = 16,000 kva
Inrush limitation = 15,000 kva
If measured on basis of full voltage at motor terminals, reduced voltage starting required.
If measured at transformer primary:
On 10,000-kva base
X_t = 0.07
X_m = 0.625
Inrush of motor and transformer in series
= 10,000 / (0.07 + 0.625)
= 14,400 kva

Fig. 6—EFFECT of point of measurement on inrush limitations

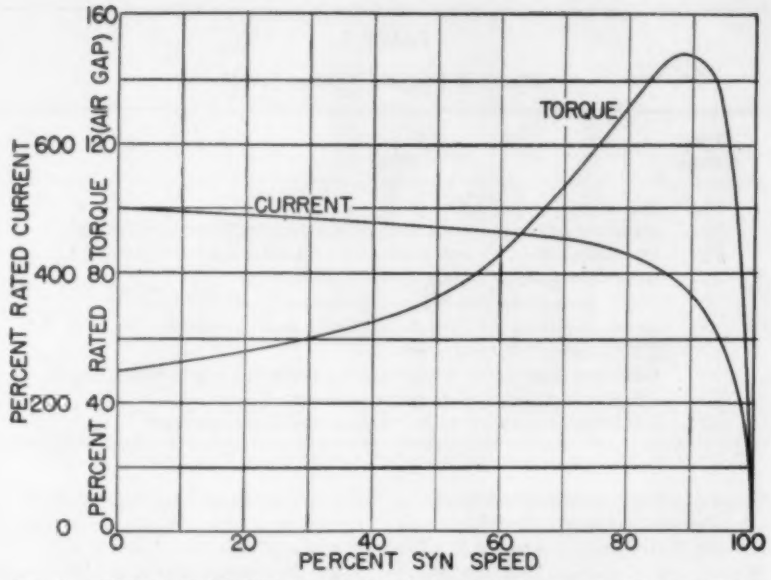


Fig. 5—TYPICAL STARTING characteristics of vertical, low-speed, 1.0 power factor, synchronous motor

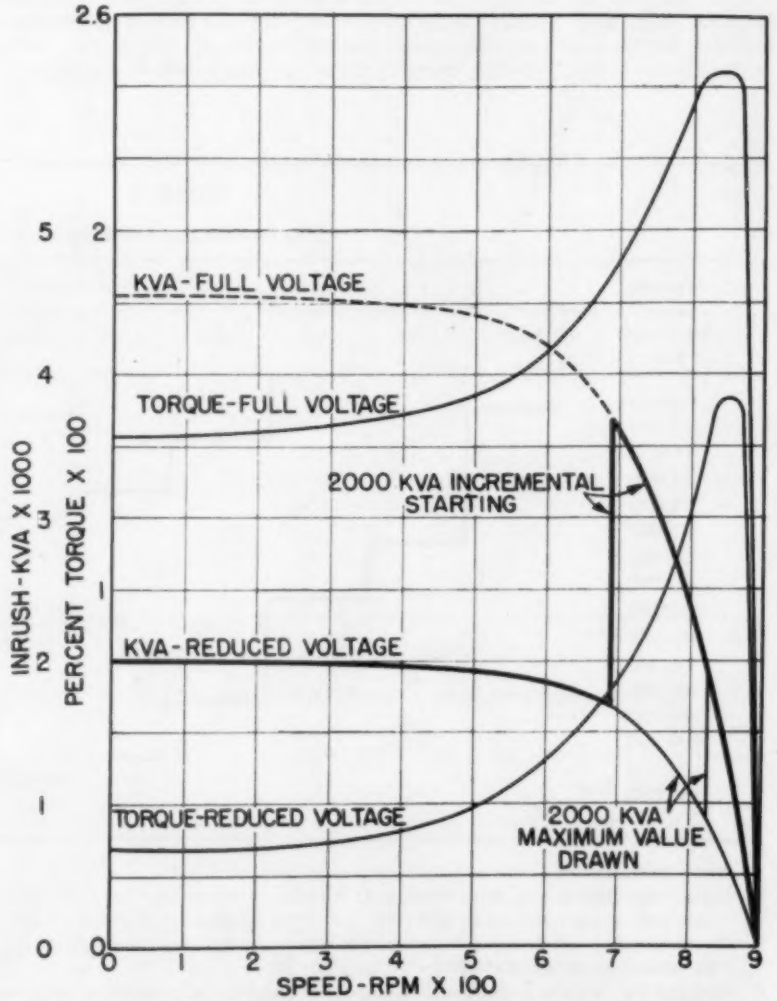


Fig. 7—FULL- AND REDUCED-voltage motor characteristics, showing incremental and maximum value inrush limitations

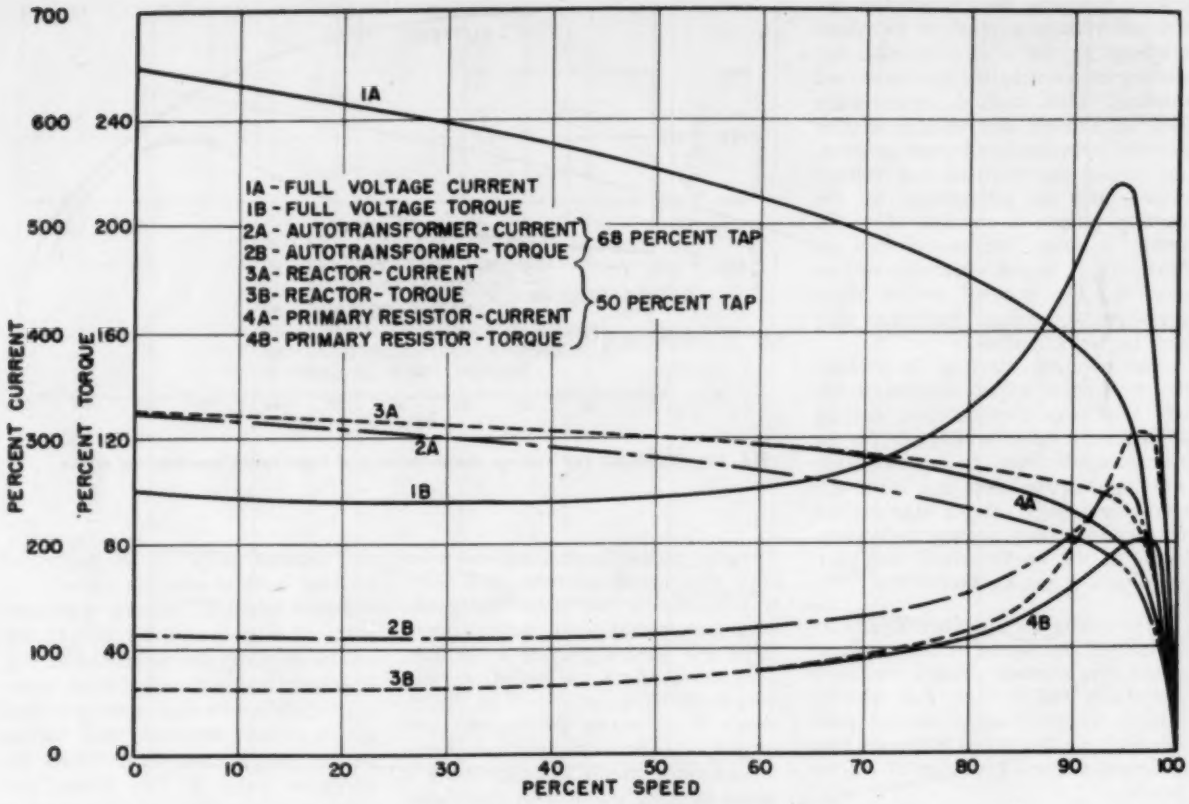


Fig. 8—EFFECTS on motor characteristics from various types of reduced-voltage starting methods

measured as increments above actual current at transfer.

It should be obvious from the foregoing that a clear, complete statement should be obtained from the power company involved on a specific job to define their current inrush limitation requirements.

Methods of Reducing Inrush

The distinct reduced inrush starting methods are:

1. Line-reactor.
2. Auto-transformer.
3. Primary-resistor.
4. Wye-delta.
5. Part-winding.

A variation of the line-reactor starter is the neutral reactor starter involving the connection of the external reactor and switching device in the neutral of the motor rather than on the line side. The advantage of this arrangement, discounting cost savings which are minor, is found in the greater flexibility in location of starting equipment compartments with possible space savings for a particular installation.

Open-transition auto-transformer starting, although generally acceptable and most commonly used, is sometimes found objectionable by electric utilities because of the momentary open circuit at transition to full voltage. This presents an occasional objectionable transient current peak during the switching operation. For this reason, auto-transformer starters are available in both open and closed (Korndorfer) transition designs. The Korndorfer starter requires (in addition to the 3-pole main line contactor) a 2-pole contactor and a 3-pole contactor in the auto-transformer circuit rather than a 5-pole contactor used in the open transition form. Consideration of auto-transformer starters should be limited almost exclusively to those applications involving contactor starting equipment because of the mechanical difficulties and high cost of providing the functional equivalent of a 5-pole switching device in a circuit breaker type of starter.

The wye-delta starting scheme, although not incorporating an external

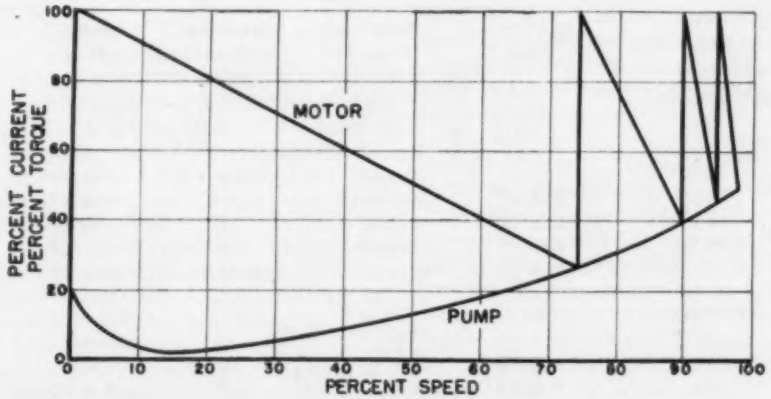


Fig. 9—CURRENT AND TORQUE characteristics of a wound-rotor induction motor accelerating a radial impeller pump

voltage dropping device, actually has reduced voltage applied to its phase windings by the wye connection for starting on a normally delta connected winding. This method, commonly used in Europe but seldom in this country, provides low torque on starting (about one-third of full voltage value)[3] and no adjustment of the starting torque is possible after the motor is built. Because of this inflexibility it is not generally recommended. The current inrush upon transition to the delta connection may also be objectionable.

Part-winding starting is perhaps the most controversial starting method. The suitability of this starting arrangement must be reviewed for the specific application. In general, part-winding starting does not offer any advantages over reactor starting for the typical pump motor application. Some of the limitations of the part-winding starting method follow:

1. Starting torque efficiency varies with type and speed of motor. Low-speed synchronous motors will have essentially full voltage, full winding torque efficiency when started part-winding. Higher-speed machines have a torque efficiency similar to reactor starting.
2. Severe torque dips may be experienced during part-winding acceleration of some synchronous and induction motor ratings. This may even give the extreme results of negative torque in a portion of the speed-torque curve.
3. Thermal and mechanical stresses in the armature windings may be more severe than with full voltage, full winding starting.
4. Smaller wire size in armature coils is necessary in many cases, giving lower mechanical strength to the coils.

Better part-winding arrangements are possible if the number of magnetic poles in the motor is evenly divisible by 3 or 4. In addition, the horsepower rating, voltage rating, and number of starting steps required are very important.

The comparative effects on motor full-voltage starting current and torque characteristics by the use of auto-transformer, reactor and primary-resistor starters have been tabulated in reference material many times before. Fig. 8 shows the full-voltage starting characteristics of a 500-hp, 900-rpm, 2.3-kv, squirrel cage induction motor and corresponding resultant characteristics utilizing various forms of reduced-voltage starting.

Under conditions of extremely stringent inrush limitations where no other constant-speed motor and starter combination will solve the problem, the wound-rotor motor pump drive will always provide a solution. This drive offers unequaled starting torque efficiency, as shown in Fig. 9, which illustrates the current and torque vs. speed characteristic for a wound-rotor motor accelerating a radial impeller pump with closed discharge and drawing no more than rated current throughout the starting range. Higher current peaks will be obtained if a higher specific speed pump is used.

In those situations where it has been established that reduced inrush starting is required, based on a complete statement of inrush limitations, the determination of the optimum starting method must be made.

Based on motor starting characteristics of Fig. 8 and 10, and closed-discharge pump characteristics of Fig. 1, reactor and auto-transformer starting methods were evaluated as to their ability to start the motor with various inrush stipulations. The results are given in Table 3. The lowest percentage kva values permitting starting are listed, below which starting was impossible or very marginal.

The general conclusions which may be drawn from Table 3 are that (a) an auto-transformer starter will generally involve a lower demand from the power supply when starting a radial impeller pump and (b) a re-

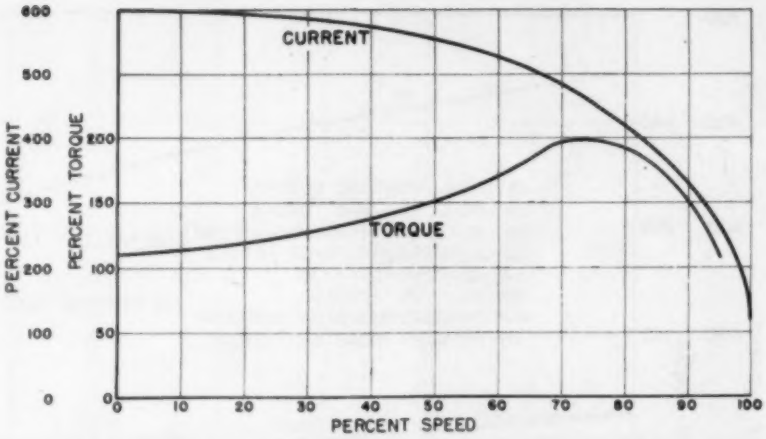


Fig. 10—TYPICAL full-voltage characteristics of high-speed synchronous motor

TABLE 3

Determining the Starting Method

% KVA Inrush Limitation	Synchronous Motor		Induction Motor	
	Mixed Flow Pump	Radial Pump	Mixed Flow Pump	Radial Pump
Max. value drawn:				
225	—	—	—	AT
300	—	R or AT	—	AT
325	—	R or AT	—	R or AT
400	R or AT	R or AT	—	R or AT
450	R or AT	R or AT	—	R or AT
520	R or AT	R or AT	R	R or AT
550	R or AT	R or AT	R or AT	R or AT
Incremental:				
220	—	AT	—	AT
300	R or AT	R or AT	AT	AT
325	R or AT	R or AT	R	R or AT

R = Reactor; AT = Auto-transformer.

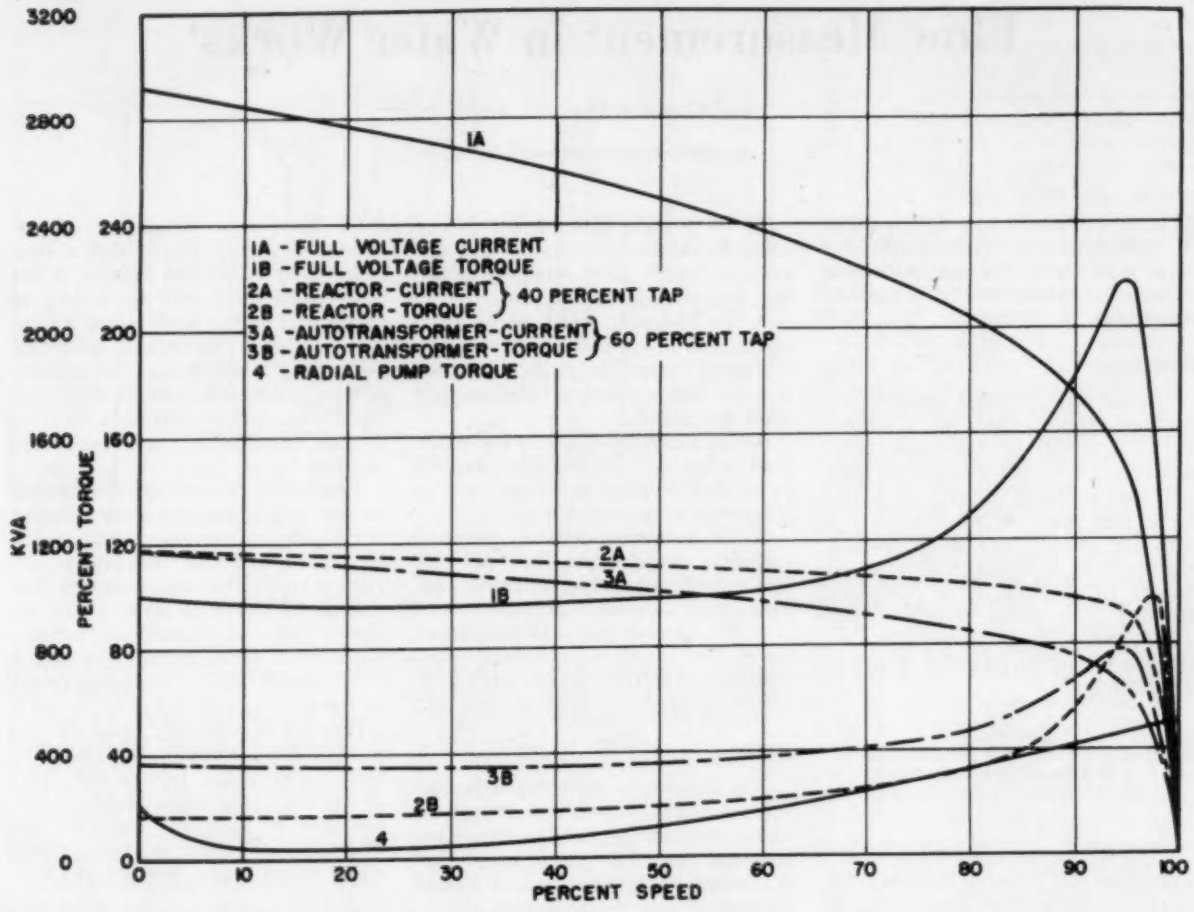


Fig. 11—MOTOR AND PUMP characteristics of typical problem

actor starter will generally afford the lowest demand when starting a mixed flow pump. There are exceptions to these conclusions which may be seen in the table, but in most cases the relative effectiveness of the two starting methods may be evaluated as stated.

Typical Problem

In order to illustrate the method of attack the following typical problem and solutions are given:

A municipality wishes to purchase a new pumping unit for an existing pumping station. The hydraulic requirements of the pump have been determined and an electric motor drive specified.

The 2,400-volt line feeding this station has a short circuit duty level of 100,000 kva and the starting inrush limitation is specified as 1,200 kva incremental.

A 500-hp, 900-rpm, horizontal, squirrel cage induction motor is required to drive the pump. The starting speed-torque curve is shown in Fig. 11, curve 4. Motor starting characteristics at full voltage are also shown in Fig. 11, curves 1A and 1B.

With this basic information it is possible to proceed with the selection of a suitable starting method.

It is apparent that full-voltage starting will not be acceptable because of the 650 per cent inrush current at full voltage. The full-voltage inrush of 2,920 kva must be reduced by a suitable starting method. The reactor starter involves the least additional expense over a full-voltage starter, so its use should be considered first.

The reactor tap required to meet an initial inrush of 1,200 kva is 1,200 ÷ 2,920, or approximately 40 per cent. The resulting speed-current and speed-torque curves are shown in Fig. 11. It may be seen that the torque provided by this voltage tap to break away the pump is inadequate and no higher tap may be used. The possibility of using a reactor starter is thereby ruled out.

An auto-transformer starter is the next best choice. This would require a tap of $\sqrt{\frac{1{,}200\text{-}100}{2{,}920}}$, or approximately 60 per cent. The 100 subtracted from 1,200 kva is the magnetizing kva drawn by the auto-transformer, usually estimated as 25 per cent of the motor full-load kva. The resulting torque and current curves using a 60 per cent auto-transformer tap are also shown in Fig. 11. Transition to full voltage at 98 per cent speed incurs a 400-kva inrush increment, which is well within that permitted by the power company.

Conclusion

Although the majority of pump motor drive applications do not involve a starting problem, this does not discount the need for careful investigation of those applications in which inrush limitations are stringent and/or load torques are severe. There exists a considerable number of variables in these two factors which must be crystallized before the optimum solution can be reached.

Flow Measurement in Water Works*

By GEORGE E. SYMONS, Ph.D.

Cons. & Tech. Editor, Larchmont, N. Y.

FLOW MEASUREMENT is a part of hydrodynamics. To understand it more fully, it is essential to understand some fundamental concepts and definitions.

Definitions

Quantity is volume contained in a confined space. *Flow* or discharge (Q) is quantity in movement past a point in a specified interval of time.

When a liquid moves in a pipe from one point to another, due to pressure (head), the quantity moving becomes the number of times the length of pipe (L) is filled and emptied in a given period of time (T). Since L/T equals velocity (V), therefore flow or quantity in motion (discharge) is

$$Q = A \times V \qquad \text{Eq. 1}$$

where Q = Vol. in cu ft per unit time (T)
A = Area of pipe in sq ft
V = Velocity of flow in ft per sec (or min) (T)

Velocity, or some function of it is a fundamental factor in flow measurement; therefore flow measuring devices are based on this concept.

Rate of Flow is the term applied to the measurement of quantity in motion for a relatively short period of time (e.g., per second, minute, hour, day).

Total Flow is the term applied to the total amount of liquid moved during a period of time, usually referring to a day, a month, or a year. Total flow equals the average rate of flow multiplied by time.

Units of flow commonly used in water works practice are: Cubic feet per second (cfs); gallons per minute (gpm); and million gallons per day (mgd).

Reasons For Flow Measurement

There are six reasons for flow measurement in a water works.

1. To provide data and information on plant production including rates of plant output as well as pressures in lines, total plant production for any period, rate of operation and total output of individual production

2. To provide information on operation efficiency, including unit operations, filters, filter washing, pumping, and well operation.

3. To provide control of unit operations, from flow measurements, including control of pumps, elevated storage tanks, chemical feeders, and filter operations.

4. To ascertain quantity of water sold wholesale to another supply, retail to individual consumer, and to determine non-revenue water.

5. To determine costs of operation including overall costs, costs per million gallons pumped, and costs of unit operations.

6. To provide records of permanence for health departments, management, or owners (either stockholders or taxpayers as the case may be).

Metering Points

The location of flow measuring devices depends on several considerations, but usually not on cost, since the total cost of meters is usually but a fraction of the total cost of a plant or system.

Individual points of flow measurement may include the following:

Source of supply—Letdown from reservoir storage, raw surface water intake, raw water pump output, both individual and total, and well field output, both individual and total.

Treatment—Flow from or to groups of coagulation and settling basins or softening units; wash water to supply tank; wash water to filters; effluent from filters, individual, groups, and total; finished water to clear wells.

Distribution—Gravity transmission mains and conduits; high service pump discharges, individual and total; elevated tank storage; and booster pump discharge.

Devices For Flow Measurement

Devices used for measuring flow may fall into one of six classes or categories: Head-area meters, functional meters, pumps, displacement meters, constant differential meters, and inertial flow meters.

Head-Area Meters are flow measuring devices used only in open channel flow or partly filled pipes; they cannot be used on lines under pressure, but are useful to measure flow from reservoirs. Head-area meters operate on the principle that a constriction or controlled barrier in the flow channel will back-up the liquid creating a higher level (head) than the level below the barrier, with that head being a function of the velocity of flow and therefore of the flow rate. Head-area meters include weirs, measuring flumes, and open end nozzles.

Functional Meters are mechanical devices which measure some function of volume in movement and which by means of other mechanical devices convert that measurement into rate of flow or total flow. There are three types of functional meters: *Differential head devices* produce a difference in head between two points of the device, and this differential is a function of velocity. These devices include the Venturi tube, Dall flow tube, insert nozzle, Gentile flow tube, and orifice. Differential head devices are used in main line metering and in metering flows at any point where water moves under pressure in a confined pipe.

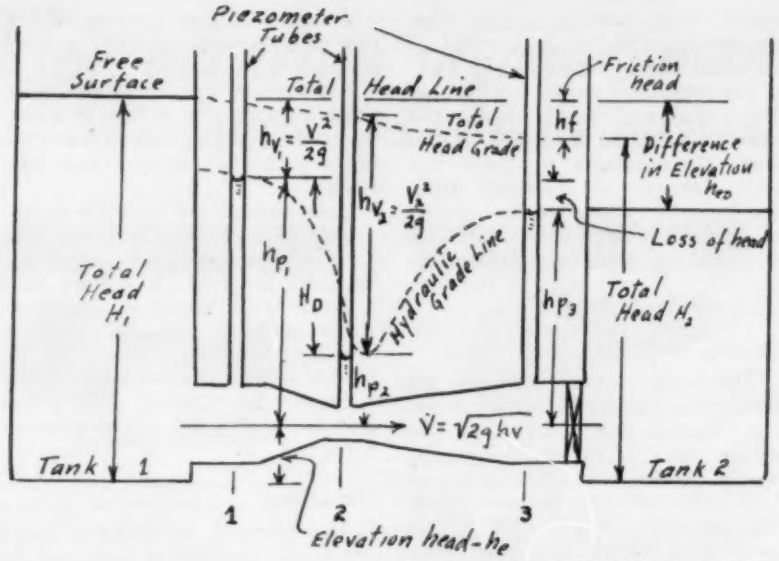
Velocity meters consist of a device by which a vane or propeller turns in direct ratio to the rate of flow past the propeller. These devices are used in main line metering, pump discharges, etc.

Pitot tubes consist of a vertical tube with a tip at right angles inserted in a flow, with the tip facing upstream. The height to which the fluid rises in the tube is a function of velocity and therefore of rate of flow. There are two other types of Pitot tubes.

Pumps may be used for measuring device, only if the number of repeat cycles can be determined. Controlled volume reciprocating pumps can be used easily for this purpose, but centrifugal pump discharges must be calibrated, for each speed of operation, suction lift or discharge head. Pumps are not generally used or recommended for flow measurement.

Displacement meters operate on the fill and draw principle. Fill and draw measurements of reservoirs and tanks can be made if the liquid entering or leaving the tank does not take place at the same time. When the fill and draw principle is applied to a closed device, a compartment is alternately filled and emptied. This is the

* Adapted from a lecture on "Flow Measurement" in a series on "Water Works Practices" in *Water & Sewage Works*, Sept. 1954, p. 395.



From B-I-F Industries Keep Sheet No. 23

Fig. 1—WATER under pressure flowing through differential producer

type of meter used for domestic water consumption.

Constant differential meters, commonly termed rotameters, consist of a tapered tube, smaller at the bottom than at the top, in which is confined a movable element termed a "float." The "float" rises proportionally in the tube as the rate of flow increases. This device is not used for measuring large flows, and has its greatest application in measuring gas flows.

Inertial flow meters do not measure volume, but determine mass by determining an inertia force of a moving mass.

Fundamentals of Flow Measuring Devices

Weirs, rectangular, trapezoidal, or V-Notch, are not used to any great extent in water works practice, but tables and charts are available to convert heads over weirs to "Q" values. (See *Wat. & Sew. Wks.,* 98, April 1951, p. R-182-R-183.) Open channel flow may be determined from measurements of heads at different points for different rates of flow and plotting rate of flow against depth of liquid. Formulas for open channel flow are not exact but give good approximations if the conduit or channel is well constructed.

Alignment charts and nomograms are available to make it easy to use these open channel flow formulas. See various Reference and Data Editions of *Water & Sewage Works* for these tables and charts.

Parshall Flume—The Parshall Flume is widely used for open channel flow measurements. It is an adaptation of the Venturi tube principle and requires exact construction limits.

The design consists of an entrance section with converging walls and level floor, a constricted throat section with parallel walls and downstream sloping floor, and a recovery section with diverging walls and rising floor. Stilling well and tap are placed in the converging section at a point two-thirds of the length of the converging section above the crest of the flume. The tap is at right angles to the wall at invert level. Dimensions must be held to close tolerances and to improve accuracy, liners of corrosion resistant material may be used.

Parshall flumes are useful where a minimum head loss is available. Accuracy depends on downstream elevation (height of surface above the floor) being held to less than a definite percentage of that upstream.

Differential Head Meters—In order to understand the operation of differential head meters it is necessary to refer to the general principles of hydrodynamics. In particular, the relations between elevation, velocity and pressure heads are important. Definitions of total head, elevation head, pressure head, velocity head, and friction head must be known in order to understand the functioning of differential head meters.

If water flowed through a smooth pipe without friction, the total head would be the same at all points in the pipe, even if the diameter or elevation of the pipe changed. When water flows in a pipe, part of the total head is converted into energy of motion (kinetic energy) capable of lifting the water to a height called the velocity head. If there were no friction, water flowing through a pipe between two elevations would have the same velocity as a body falling freely between those two elevations or $V = \sqrt{2gh_v}$, where h_v is the height fallen.

In any pipe, regardless of friction or variation in cross-sectional area of the pipe, an equal quantity of water must pass all points at the same instant. This is the principle of "Continuity of Quantity" and is fundamental in the operation of differential head meters.

If a constriction is inserted in a piece of pipe (as shown in Fig. 1), the theory of differential head meters can be understood. With the valve closed, water does not flow and water in the piezometer tubes stand at the same elevation as the free surface in Tank 1. When the valve is opened, water will flow because of the difference in elevations between the two tanks. Part of the total head will be converted to veloc. head at point 1.

The same quantity of water must pass points 1 and 2 during the same time interval; therefore the velocity at point 2 must increase proportionately to the decrease in cross section area. At the same time as the velocity increases, the velocity head increases and the pressure head decreases. The greater the velocity, the lower the pressure head at the constriction.

Therefore, the difference in pressure head between the inlet and the constricted portion of a differential head producer is a measure of velocity which is a function of rate of flow. The rate of flow varies as the square root of the difference in pressure at the two points. This difference is called "differential head" or simply "differential." The greater the differential produced the more accurate is the determination of rate of flow.

The increase in velocity is equal to $\sqrt{2gh_D}$, where h_D is the differential head and the flow formula derived from Equation 1 above, becomes

$$Q = A \times \sqrt{2g(h_D + h_{va})} \quad \text{Eq. 2}$$

where Q = cu ft
A = cross section area in sq ft
h_D = Differential head in ft
h_{va} = Velocity head corresponding to velocity of approach at the inlet.

The velocity of approach cannot be observed but it can be converted into a *velocity of approach* factor expressed as $1/\sqrt{1 - \beta^4}$, where β is the Beta ratio, or ratio of diameter of the inlet (d) to the diameter of the

throat (D), (that is, $\beta = d/D$).

Because of friction, water passing through any differential head producer loses some energy. This loss appears as a decrease in head (h_f) and is known as "loss of head" or simply, "head loss" (See Fig. 1). Head loss means power loss or need for power to overcome the head loss. Therefore, the most desirable characteristics in a differential head producing device (often referred to as the primary unit) are maximum differential and minimum head loss.

Venturi Type Flow Tubes—The Dall Flow Tube is an accurate primary measuring device, which has the lowest permanent head loss (greater recovery of loss of head) of any known type of velocity-increasing differential producer. The Dall Flow Tube consists of a flanged cylindrical body designed with a short straight line section that terminates with an abrupt decrease in diameter, or "inlet shoulder." This shoulder is followed by a conical restriction and a narrow annular gap, called the slotted throat annulus. The annular gap is followed by a diverging outlet "cone."

The Gentile Flow Tube consists of a device with a slight constriction in the walls of which there are pressure nozzles or ports, some facing upstream, some downstream.

One advantage of Venturi type flow tubes is the short laying length and low weight. Other advantages are described in manufacturers' bulletins.

Orifices—An Orifice is a thin flat plate, in which there is an opening smaller than the pipe in which the orifice plate is inserted between flanges. A concentric orifice has a circular opening at the center of the pipe, an eccentric orifice has a circular opening tangent to the inside wall of the pipe. A segmental orifice has an opening bounded by the inner wall of the pipe and a chord of that circle.

The orifice is, in effect, a dam behind which solid particles will collect. Fluids passing through orifices show a permanent loss of head of 40 to 90 per cent of the differential head depending on the Beta ratio of the orifice (that is, the recovery is 10 to 60 per cent).

A slight increase in pressure occurs just ahead of an orifice; there is a sudden drop in pressure on the downstream side of the orifice and a continued pressure drop before recovery starts. The point of minimum pressure (maximum velocity) is known as the Vena Contracta. Full information on installation and use of orifices may be found in standard reference texts on hydraulics.

Insert Nozzles—A nozzle-like concentric throat section, smaller than the pipe in which it is inserted, is called an insert nozzle.

The simplest form is, in effect, an orifice plate with a cylindrical nozzle extending beyond the plate. It has many disadvantages of the orifice plate. Variations of the insert nozzle are designed to improve the recoverable loss-of-head. These include the ASME long radius nozzle, the Venturi Flow Nozzle and the Builders-Schlag-Jorissen Tube.

Selection of Primary Units

The device which measures the flow (weir, Parshall flume, open nozzle, Venturi tube, Dall flow tube, orifice, etc.) is called the primary unit. Considerations affecting the selection of primary devices include type of service, engineering factors, installation factors, accessories, comparative characteristics, and operators convenience.

Principal engineering factors to be considered include allowable permanent loss of head, size of the constriction, differential pressure, flow disturbance due to upstream and downstream conditions (bends, valves, etc.), distance to secondary unit, and type of transmitter required.

Selection of a primary measuring device can be simplified by comparing several characteristics common to all. These characteristics include: Accuracy, cost, capacity, range, permanent head loss, life expectancy, freedom from field tapping, freedom from upstream disturbances, ability to handle liquids containing solids, ability to handle high pressures, laying length, and ease of installation.

A table (Builders-Providence, Inc. Tech. Memo H4A) shows a comparison of all these characteristics on a per cent basis with 100 per cent representing the device having the best performance in the characteristic listed.

Secondary Instruments

A secondary instrument or receiver is the device used to convert measurements, sensed by and transmitted from the primary measuring unit, into observable information on flow. (Liquid level and pressure also can be shown on secondary instruments.)

Secondary instruments are classified in two ways—(a) According to type of information desired and (b) according to method of transmission from primary to secondary unit.

Classes by type of information desired include:

Indicator—Shows rate of flow, at moment of observation, in cfs, gpm, gph, mgd, etc.

Totalizer—Shows running total to time of observation, in cu ft, gal, mil gal, etc.

Recorder—Gives drawn record on chart, showing rate of flow as a continuous record for each instant during a particular period (hour, day, week).

Combinations are available as Indicator-Recorder, Totalizer-Indicator, Totalizer-Recorder, and Totalizer-Indicator-Recorder. Indicators have a single arm and dial. Indicator-Recorders may have the indicator arm separate from the chart, or indicator arm attached to the pen arm.

Classes by type of transmission include: Mechanical, electrical, pneumatic.

Transmission

Mechanical transmission exists when the receiver is operated by cables directly connected to float wells which are in turn connected to the pressure takeoffs (taps) of the primary device. Mechanical transmission also may be produced by connecting the primary device pressure taps directly to mercury wells in the receiver unit.

Electrical transmission is used where the receiver cannot be located near the primary unit or where there is insufficient pressure for direct connection of primary to secondary unit. Electrical transmission is of the time-impulse type (Chronoflo Telemeter) whereby the length of time that the signal is transmitted is proportioned to the magnitude of the function being measured, (rate of flow, pressure, level, etc.). This signal can actuate a receiving instrument, control pumps, chemical feeders or valves, or both. Electrical transmission is possible over any distance from feet to miles, over telephone circuits, private A.C. or D.C. lines, or multi-service wires. A sequencing unit (Sequence Unit Transmitter) will transmit signals from several transmitters consecutively over the same pair of wires. Sequencing is useful in the operation and control of well field pumps and booster pumping stations.

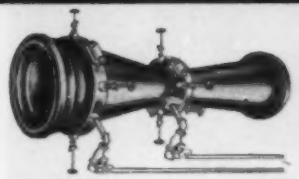
Pneumatic transmission is useful up to 1500 feet; it generally makes use of a varying controlled-air-pressure ranging from 3 to 15 psi. Principal features are absence of wiring, continuous output signal (pressure), extreme sensitivity to change in variable being measured, and in immediate response to change in variable.

Secondary instruments, their design, operation, and application, and their use in control functions are all part of the general subject of instrumentation and control.

For accurate measurement and control

SPECIFY THIS RELIABLE SIMPLEX EQUIPMENT

VENTURI TUBES

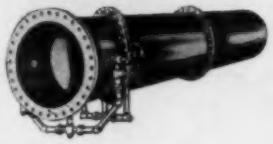


Accurately measure sewage, sludge, trade wastes under a wide range of pressures. Flanged, bell or spigot ends in any size or design . . . any metal.

Cleaning valves at main and throat keep piezometer openings clear.

WRITE FOR CATALOG 005

ELLIPTICAL VENTURI TUBES

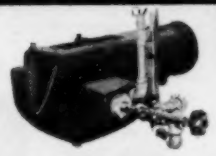


Developed specifically for *accurate* measurement of low velocity sewage, sludge or heavily laden trade wastes—flowing under low pressures.

Flat top prevents air binding! Flat invert is self-scouring!

WRITE FOR BROCHURE

PARABOLIC FLUMES



Measure sewage, sludge and trade wastes under low heads or open flow. Can be used for indicating, or with meter to record and totalize. Simple to install. Full 20 to 1 flow range. Flanged, bell or spigot inlet in 6" to 36" standard pipe sizes.

WRITE FOR BULLETIN 801

SLUDGE CONTROLLERS

Accurately control flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex Venturi Tube, has a special throat section of flexible rubber—measures as it controls! Motor-driven clamp adjusts throat . . . keeps flow at control point. Viscous flows contact no moving parts.

WRITE FOR BROCHURE

TYPE MO METERS

Most accurate inferential type instrument for water, sewage, sludge, industrial liquors. Indicates, records, totalizes.

Measures within ±2% over ranges up to 20 to 1. Easy-to-read chart. Wall, floor stand, or panel mounting.

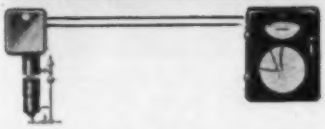
WRITE FOR BULLETIN 500

TYPE H METERS

Mercury-float type indicating, recording and totalizing unit. Gives ±2% accuracy at any point for flow ranges up to 13 to 1. Evenly spaced scales make accurate readings easy. Wall, panel, or floor stand mounting.

WRITE FOR BULLETIN 402

ORTHOFLOW® TRANSMITTER



Electric—New Simplex Orthoflow transmits data over in-plant circuits and leased telephone channels. Accuracy of ±2% for wide ranges.

Receiver—Reliable Type H Meter.

WRITE FOR BULLETIN 700

LAMINAIR® TRANSMITTER

Pneumatic—New Simplex Laminair is fast and accurate. Permits centralizing instruments in main control panel away from primary devices.

Receiver—Reliable Type H Meter.

WRITE FOR BULLETIN 750

AIR RELEASE VALVES

Specially designed for sewage lines. Vent air accumulations to eliminate binding at high points, increase pumping efficiency. Special vacuum-holding attachment vents air without causing loss of prime.

The 2" size is adaptable for installation on all pressure lines, pump casings.

WRITE FOR BULLETIN 1204

OTHER SIMPLEX PRODUCTS

FLOW RATE CONTROLLERS

INSERT-TYPE VENTURI TUBES

LARGE DIAL GAUGES

SPECIAL AIR VALVES

FILTER OPERATING TABLES

Write for information today!

SIMPLEX
VALVE AND METER COMPANY

SIMPLEX VALVE & METER COMPANY ● **Dept. WS-13, 7 E. Orange St., Lancaster, Pa.**

Gentile* FLOW TUBES

For Accuracy in Metering

*Gen-til'-ly

This 78" Gentile Type D Flow Tube of welded steel construction is only 78" face to face, and weighs only 8900 lbs.—many feet shorter and several thousand pounds lighter than a conventional venturi.

It is designed to handle 120 MGD of water at 60 PSIG and 68°F with a maximum head loss of 12" H_2O at these operating conditions, and with an accuracy within ±1% of the calibration curve furnished with it.

The Gentile Flow Tube is an impact-type head meter (differential producer) designed for accurate measurement and regulation of fluid flow. It consists, essentially, of a short spool piece, the inner periphery of which is equipped with two groups of pressure nozzles, one group pointing upstream and the other downstream. The nozzle groups are inter-connected by common pressure rings from which connections are made to the high and low pressure sides respectively, of a conventional indicating, recording or integrating meter. Flow Tubes differ from other variable head meters in that the taps are located at points of equal cross-sectional area. Therefore, the differential developed is a function of the velocity head and independent of the static head.

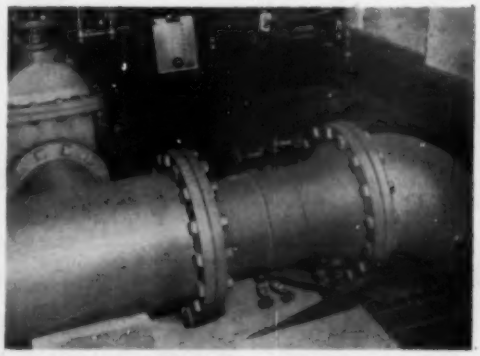
Flow Tubes are compact, comparatively light weight, relatively low in cost, and are easy to install since they require straight runs entering and following only when installed near throttling valves or regulators. And, Flow Tubes are available in types and D/d ratios to provide differentials that can be accurately measured with the least head loss.

Flow Tubes are furnished with head capacity curves based on laboratory tests. These data furnished with each Flow Tube makes our guarantee of exceptional metering accuracy possible.

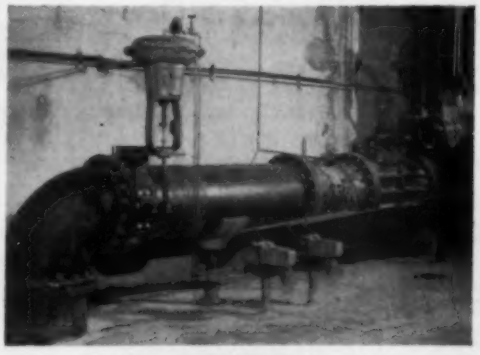
For further information, write us, and for specific recommendations, send us necessary flow data.

TYPICAL INSTALLATIONS

16" Gentile Flow Tube in Waterworks Pumping Station



12" Gentile Flow Tube in a Long Island Waterworks Pumping Station connected directly to 90° El.



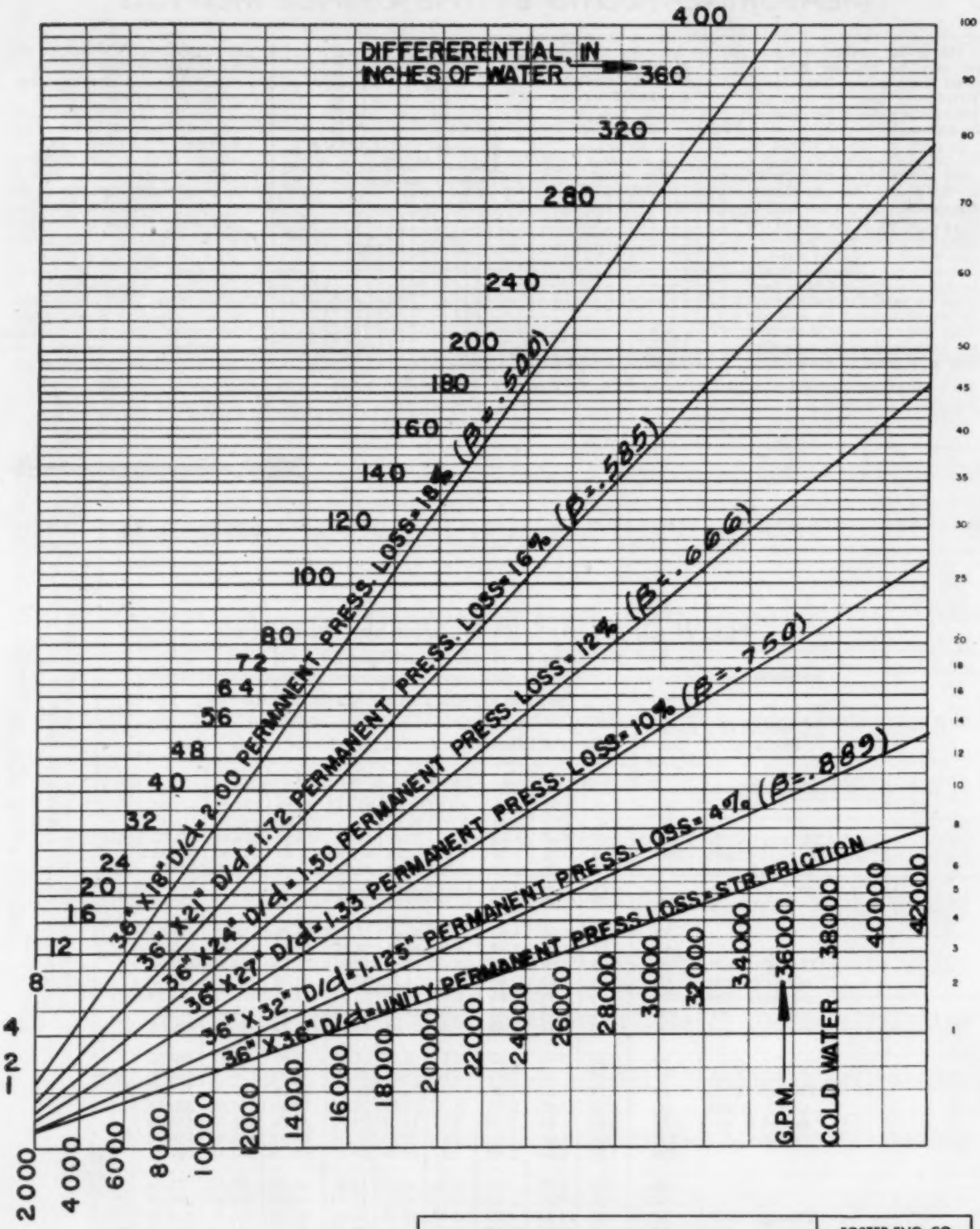
One of twelve 20" Gentile Flow Tubes in Corpus Christi, Texas Filtration Plant

FOSTER ENGINEERING COMPANY

827 Lehigh Ave., Union, N. J.

Agents in Principal Cities.
Consult your Classified Telephone Directory.

AUTOMATIC VALVES • CONTROL VALVES • SAFETY VALVES • FLOW TUBES



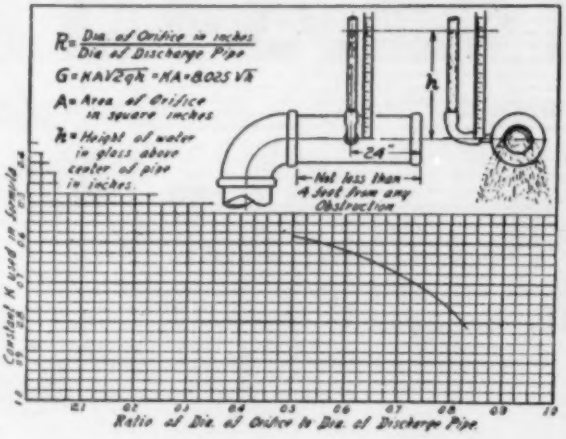
HEAD CAPACITY CURVES 36" TYPE D GENTILE FLOW TUBES FOR VARIOUS D/d RATIOS	FOSTER ENG. CO. UNION, N. J.
	DATE
	CHECKED
	SQUARE ROOT CHART

MEASURING FLOWS BY THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose


R = Dia. of Orifice in inches / Dia. of Discharge Pipe
G = HAV2gh = HA = 8.025 √H
A = Area of Orifice in square inches
h = Height of water in glass above center of pipe in inches
24"
Not less than 4 feet from any Obstruction
Constant K used in formula
Ratio of Dia. of Orifice to Dia. of Discharge Pipe

is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.

Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience when determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

FLOW OF WATER IN HOUSE SERVICE PIPES

(To find the discharge in gallons, multiply by 7.48)

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe								
		Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215 68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	?54.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

ORIFICE TABLE FOR DETERMINING WATER FLOW

Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in Hydraulic Laboratories at Purdue University.

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	393	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1353	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	643	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	295	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1013	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	235	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	239	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	247	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	1259	36.5
37	257	203	385	358	748	592	943	857	1266	37
37.5	259	204	388	360	754	596	949	862	1274	37.5
38	260	205	390	363	759	600	955	867	1281	38
38.5	262	206	393	365	765	604	961	872	1289	38.5
39	263	208	396	367	770	608	967	877	1295	39
39.5	265	209	398	369	776	612	974	882	1304	39.5
40	266	210	401	371	781	616	979	887	1311	40
40.5	267	211	403	373	786	620	985	891	1319	40.5
41	269	212	406	375	790	624	990	896	1326	41
41.5	271	213	408	378	795	628	996	901	1334	41.5
42	272	214	411	380	800	631	1001	906	1341	42
42.5	274	216	413	382	805	635	1007	910	1349	42.5
43	275	217	415	384	810	638	1012	915	1356	43
43.5	277	218	418	386	815	642	1018	920	1364	43.5
44	278	219	420	388	820	645	1023	925	1371	44
44.5	280	220	422	390	824	649	1029	929	1379	44.5
45	281	222	425	392	828	652	1034	934	1387	45
45.5	283	223	427	394	832	656	1040	939	1394	45.5
46	284	224	429	396	837	659	1045	944	1401	46
46.5	285	225	432	399	842	663	1051	948	1409	46.5
47	287	227	434	401	847	666	1056	953	1416	47
47.5	289	228	437	403	851	669	1062	958	1424	47.5
48	290	229	440	405	855	672	1067	963	1431	48
48.5	292	230	442	407	859	676	1073	967	1439	48.5
49	293	231	444	409	863	679	1078	972	1446	49
49.5	294	232	446	411	868	683	1084	977	1454	49.5
50	296	234	448	413	872	686	1089	982	1461	50
50.5	298	235	450	415	876	690	1095	986	1469	50.5
51	300	236	453	417	880	693	1100	991	1476	51
51.5	301	237	455	419	884	697	1105	996	1484	51.5
52	302	238	457	421	888	700	1110	1000	1491	52
52.5	303	239	459	423	892	704	1115	1005	1499	52.5
53	304	240	461	425	896	707	1120	1009	1506	53
53.5	305	241	463	427	900	711	1125	1014	1513	53.5
54	307	243	465	429	904	714	1130	1018	1520	54
54.5	309	244	467	431	908	718	1135	1023	1527	54.5
55	310	246	469	433	912	721	1140	1027	1534	55
55.5	311	247	471	435	915	725	1145	1032	1541	55.5
56	313	248	472	437	919	727	1150	1036	1548	56
56.5	314	249	474	439	923	730	1155	1040	1554	56.5
57	315	250	476	441	927	733	1160	1044	1560	57
57.5	316	251	478	443	930	736	1165	1046	1567	57.5
58	317	252	480	445	934	739	1170	1052	1574	58
58.5	319	253	482	447	938	742	1175	1056	1580	58.5
59	320	254	485	449	942	745	1180	1060	1586	59
59.5	321	256	487	451	945	748	1185	1064	1592	59.5
60	323	257	489	453	948	751	1190	1068	1598	60
60.5	324	258	491	455	951	754	1195	1072		60.5
61	325	259	492	457	955	757	1200	1076		61
61.5	326	261	494	459	958	760	1205	1080		61.5
62	328	262	496	461	961	763	1209	1084		62
62.5	329	263	498	463	964	766	1214	1088		62.5
63	330	264	500	465	968	769	1218	1092		63
63.5	331	265	502	467	971	772	1223	1096		63.5
64	333	266	504	469	974	775	1227	1099		64
64.5	334	267	507	471	977	778	1232	1103		64.5
65	335	268	509	472	981	781	1236	1106		65
65.5	336	269	511	474	984	784	1241	1110		65.5
66	338	271	513	475	988	787	1245	1113		66
67	340	273	517	479	995	793	1254	1120		67
68	343	275	520	483	1002	799	1263	1127		68
69	346	277	523	487	1009	805	1272	1134		69
70	349	280	525	491	1016	811	1280	1140		70

Automation in Water & Sewage Works*

Its Present and Future

by B. L. Soscia and R. W. Lindsey
B-I-F Industries, Inc., Providence, R. I.

AUTOMATION—A coined word which denotes "automatic operation." It is not new; the first automatic plant was a grain processing mill in Philadelphia in 1784 where grain was unloaded from a boat or wagon and processed to finished flour without human aid. Automation is not something for tomorrow, it is here today.

For persons working in the field of sanitary engineering these questions may arise: What is it? What are today's applications? How soon will other applications be available? What can it bring in the future? What will it mean to workers in the field? In this article, the authors answer those questions with predictions of the future and statements of facts as to the present.

What is Automation

Mechanized equipment control dates back five centuries, when sails were placed on windmills to keep them facing into the wind. Control of start-stop operations of modern power equipment began with valves on steam engines and switches on electric motors. Semi-automatic control became a reality when the operation of one device was controlled or paced by the operations of another device. Automatic operation or automation added one new factor, the principle of "feedback." Modern automatic operations have adapted the principle of feedback to the many modern means of transmitting information.

M. H. Aronson, Editor of *Instruments and Automation* has defined automation as "the substitution of mechanical, hydraulic, pneumatic, electric and electronic devices for human organs of decision and effort." In short, automation is automatic control initiated or monitored by a feedback signal. This principle of feedback means simply that the result of some operation is sensed or measured and the magnitude of that measurement is returned (fed back) to control the operation so that the result will be maintained within definite and desired limits.

Plant of the Future

Applications of semi-automatic and automatic control have appeared in water and sewage works for a number of years, but what is the future of automation in the field of sanitary engineering? Some comparison with other fields may give the clue. Both chemical processing and petroleum refining have found wide applications of automation. Both involve unit processes of operation. Water and waste-water treatment also involve unit operations (pumping, coagulation, sedimentation, filtration, aeration, chlorination, etc.) Therefore, it may be expected that automatic operation of water and sewage plants is both feasible and probable.

The writers asked M. E. Rogers, Manager, Engineering Projects, of Builders-Providence, Inc. and a former water works superintendent, to suggest the "dream water plant" of the future. Mr. Rogers wrote: "It is probable that the water plant operator of the future will not see the filter he backwashes except perhaps by closed circuit television. There are three current trends which will lead to this situation: (1) to eliminate all unnecessary construction in order to save on initial cost; (2) to cut settling time to 20 or 30 minutes, at the most; and (3) to make full use of automatic controls.

"The future laboratory will be equipped with an automatic analyzer where samples of both raw and finished water will be continuously analyzed and the information, along with flow data, will be fed into a computer mechanism which, in turn, will ad-

*A paper presented at the 6th Annual Conference on Sanitary Engineering of the University of Kansas, Lawrence, Kan.

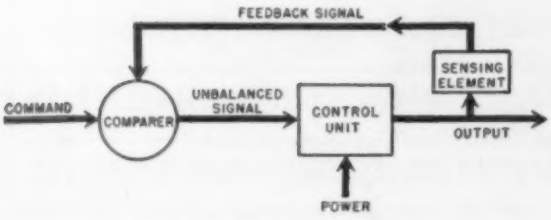


Fig. 1—SINGLE control loop

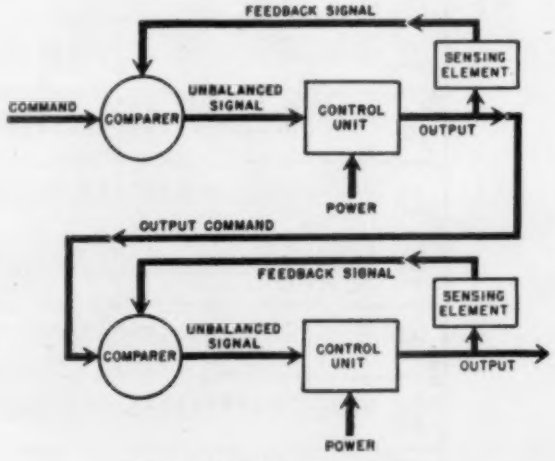


Fig. 2—CASCADE control loops

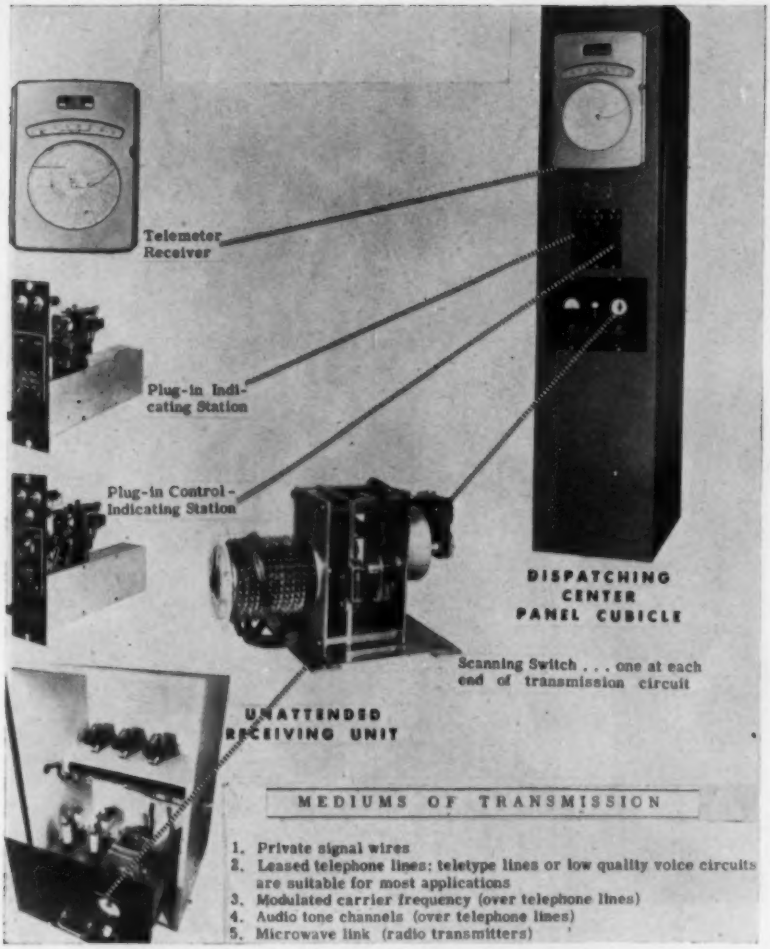

Telemeter Receiver
Plug-in Indicating Station
Plug-in Control-Indicating Station
DISPATCHING CENTER PANEL CUBICLE
Scanning Switch . . . one at each end of transmission circuit
UNATTENDED RECEIVING UNIT
MEDIUMS OF TRANSMISSION
1. Private signal wires
2. Leased telephone lines: teletype lines or low quality voice circuits are suitable for most applications
3. Modulated carrier frequency (over telephone lines)
4. Audio tone channels (over telephone lines)
5. Microwave link (radio transmitters)

Fig. 3—TRANSMISSION system—Scanning switch sequencing

just the chemical feeders to provide a predetermined minimum residual amount of turbidity, hardness, and taste and odor as well as the proper amount of chlorine for disinfection. On hard waters, a portion of the water will be passed through a demineralizer operating along electro-osmotic principles and recombined with a second portion which has merely been clarified to secure a predetermined final product containing just the right amount of the chemicals desired in solution.

"Wherever possible and particularly in larger plants, chemicals will be handled in solution or suspension to eliminate dust and save storage space. Solutions can be pumped to point of application and the need for high chemical head houses will be eliminated. Filters will be backwashed automatically, initiation being on the basis of maximum loss of head and termination of the washing period on the basis of turbidity in the waste water. Rate of backwashing will be controlled by sand size and expansion.

"Safeguards will be provided all along the treatment path to detect and prevent errors in operation. Closed circuit television may be used. Operating controls will be centralized in the chemical laboratory where a complete instantaneous picture of operation will be recorded on a continuous strip chart. Operator's duties will consist of checking calibration of various devices, renewing standard reagents in analyzing equipment, ordering chemical supplies, preparing statistical reports and supervising maintenance. The operator of the future will be a process supervisor who will be a trained engineer with a complete background in sanitary engineering plus knowledge of electronics and automatic operation.

"Except in emergencies, no one will adjust a valve to regulate rate of through-put, or start-stop of pumps. Flow through the plant to the consumer will be fully automatic at pressures and rates required by the conditions of demand on the distribution system. It is possible that the electron microscope will continually scan the final effluent and with a television feedback will control disinfection or sound an alarm to the community if the disinfection process fails."

The writers also asked Walter H. Brown, Project Engineer of Builders-Providence, Inc. and a former sewage works superintendent, for his ideas on the sewage works of the future. Mr. Brown wrote: "In the future waste treatment plant processes will be controlled automatically thereby requiring only trained supervisors and maintenance technicians. Sewage will be delivered to the plant by means of automatically controlled lift stations where pumps will operate in accord with flow requirements; will regularly rotate to distribute wear; and will cut out of service when partially clogged, with a warning signal to the central station to dispatch maintenance men for cleaning operations.

"For primary treatment, automatically cleaned trash racks and comminutors will precede grease removal units and primary settling tanks. Grease will be skimmed off and sludge removed in accord with the load or accumulation of each in their respective tanks. Both sludge and grease will be concentrated, seeded with special organisms and enzymes to produce chemicals or gases of commercial value, and pumped to digestion tanks which will operate at automatically controlled temperatures with the digestion process controlled by the end product produced. Sludge from these tanks will be washed, filtered and dried for soil conditioning use and the amount of washing, amount of chemicals for dewatering, vacuum filtration and heat drying will be controlled according to the sludge load which in turn will be governed by the results of the digestion process.

"For secondary treatment, trickling filters or activated sludge will operate at rates in accord with the incoming load and the final results of the process as determined by turbidity, suspended solids and oxygen demand or dissolved oxygen and bacterial content. Rates of return sludge or amounts of artificially added oxygen will be controlled from the same device that determines the condition of the final effluent. Disinfection by chlorine or other disinfectant will be controlled by a continuous analysis of the bacterial content of the effluent and/or the chlorine required value. Sludge from both primary and secondary settling units will be pumped in accord with the rate of accumulation and will be

thickened automatically to the optimum water content. Rate of pumping and start-stop of operations will be in accord with the density or concentration of the sludge so that a constant composition of sludge-water ratio will be fed to the digesters.

"Whether or not new processes of treatment appear, there is no doubt that all sewage treatment plants can be made to run by automatic process as soon as the necessary sensing elements or analyzers are available."

How Automation Works

It is apparent from the definition of automation and from the description of the water or sewage plants of the future that there are certain essential elements to an automatic control system. These include: sensing element, transmission system, instrument or comparer unit, control unit, and power to do the work.

To understand how these elements fit into the operations of a water or sewage plant it is necessary to list the operations which have been performed by a human operator. These basic operations may be listed as follows:

1. Determine point where change is necessary; this determination may be based on the reading of meters or gauges, chemical analysis, or other observation.
2. Dispatch a command to perform or advise (start-stop or adjust equipment operation).
3. Sense error in process (human judgment).
4. Read instruments or make check analysis to compare changes with position or magnitude of result intended by command (feedback).
5. Note error and take corrective action to minimize new error (feedback).
6. Record data on the progress of the complete operation.

Any operating plant utilizing human decisions and efforts to perform step operations, will invariably be the victim of costly errors. Even when operating normally, an operator (or several) is being paid for merely standing by, a costly situation. When something goes wrong, human judgment is called upon to correct the fault. In performing this corrective action, the operator becomes the feedback mechanism, (step No. 5 above), and is limited in speed, response and ability to calculate the next move. It is this step No. 5 which is an essential in a true automation system. When the operator is bypassed or has substituted for him mechanical, electrical, hydraulic, pneumatic, or electronic devices, the automatic plant results.

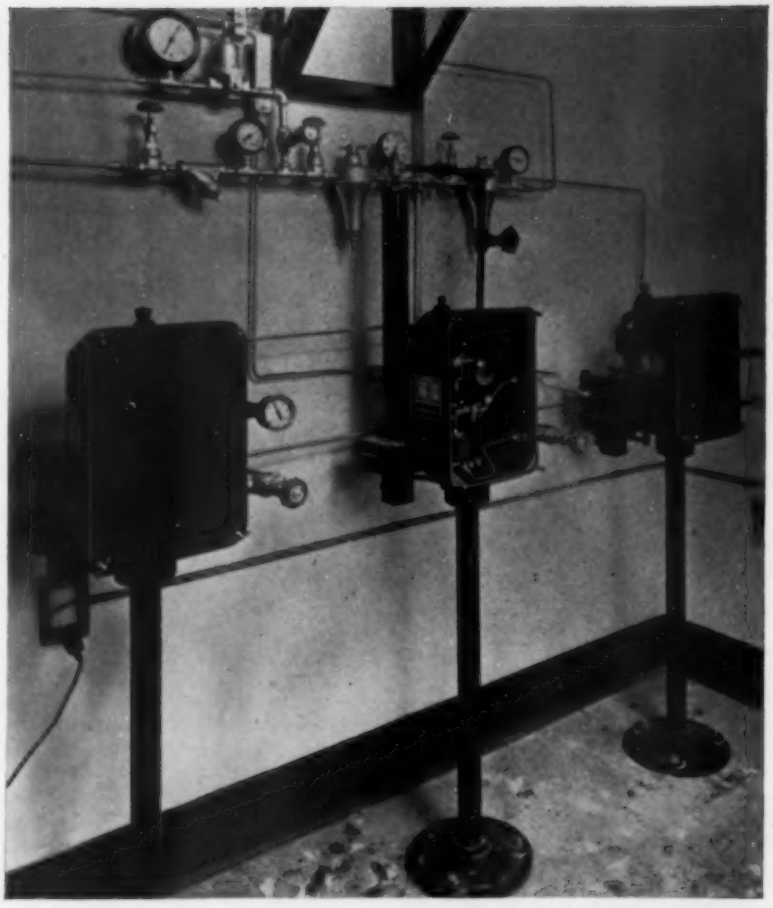


Fig. 4—RATIO computer transmission by air
Air-sewage ratio at Hyperion Sewage Plant, Los Angeles, Calif.

In water or waste treatment involving stepwise unit processes, complete automation is best accomplished by cascade or "piggyback" control. This system forms a series of linked control systems each controlling within its link, while the material being processed feeds into successive operations. Figure 1 shows a single feedback control system in block form. Figure 2 shows a cascade control composed of two links in which the output of the first becomes the command for the second. This cascade system can be built up stepwise to cover the entire operation of an automatic water or sewage plant.

Where Are We Today?

In discussing the status of automation in water and sewage works today, it is desirable to review both the equipment and the applications now in use. The best approach to this matter is to consider first, the four elements of an automatic control system: Sensing element, transmission, comparer unit, and control device.

Sensing Element

Today there exist excellent devices for the measurement of pressure, temperature, fluid flow, pH, oxidation-reduction potential and conductivity. All of these items have been in use for many years. More recent developments include devices for determining residual chlorine, turbidity, and dissolved oxygen. For completely automatic operation, we need improvement in the last three items mentioned, and we need wholly new devices for the determination of the optimum point of coagulation, the filterability of water, the fluoride content of water, the hardness of water, the chlorine demand of water and sewage, the B.O.D. of sewage, the bacterial content of both water and sewage, (perhaps the electron microscope). Also needed are devices for determining the ammonia, alkalinity and volatile acid content of sludge digestion tank liquor, moisture content of sludge, et cetera. And all of these devices must be capable of determining these characteristics on a continuous basis.

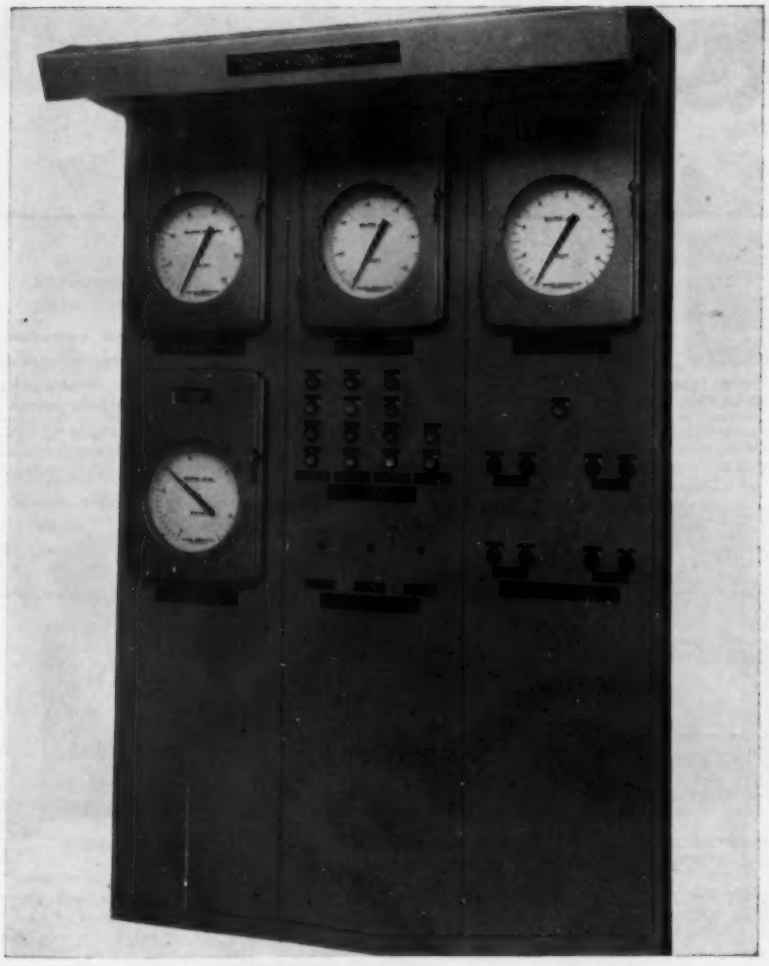


Fig. 5—CONTROL panel for pumps in sewage works

New sensing devices must have the same basic characteristic existing in present sensing elements. They must be able to convert the sensed information to some physical manifestation represented by mechanical motion (linear or rotational) pneumatic pressure (or mechanical motion), or electrical voltage or frequency. Electrical manifestations are generally preferred because of the ease of transmission over great distances, speed of response, and versatility in combining with other electrical data.

Transmission

There are many transmission systems available for use. These include direct mechanical linkage, hydraulic pressure, pneumatic pressure, electric signal, electronic signal, audio wave and radio micro-wave link. Probably best known in the sanitary engineering field are the mechanical link (cable), pneumatic (air pressure) and electric telemetering systems.

Transmission elements have long been used in remote supervisory control systems, especially where raw water pumps, deep well pumps or sewage lift stations are located at some distance from the main station. These supervisory control systems are used not only for start-stop of equipment and speed control but also to report back operating conditions such as running speed, valve position, bearing temperatures, pressures, flow, etc.

If a water treatment plant is located reasonably near the source of water, the problem of controlling and monitoring is greatly simplified. Multi-wire cables can be used for transmitting control functions or commands from the plant mixing basins to the pumps and feeding back operating conditions such as pump status, pressures, flow and other data which may be used to regulate other steps in the process or stored on charts for future expansion and efficiency studies.

If the treatment plant is located at some distance from the source of supply, the problem of remote control becomes involved because of the economies of the transmission system and therefore has a bearing on the ultimate control system chosen. The choice is always narrowed down to supervisory control over a single pair of leased telephone or private wires or radio (micro-wave link). In the final analysis, the choice usually goes to signal line transmission because of its simplicity, lower cost and lack of external interference from electrical obstacles.

Supervisory control systems for use over leased or private signal lines are classified basically as one of three types:

a. All relay pulse coded (G.E. and Westinghouse)
b. Tone coded (R-F Labs. and Hammarlund)
c. Scanning switch sequencing (Builders-Providence Synchro-Scan® Supervisory Control, Fig. 3)

Combinations of these basic types result in systems which can be described as:

d. Relay and tone coded.
e. Relay tone coded and stepping switch.
f. Tone coded and scanning switch.

Of these several systems, the scanning switch sequencing type of supervisory control is an excellent system for use in water and sewage treatment processes because it was designed specifically for that field. The Synchro-Scan system can perform all of the automatic functions required in addition to report back and telemetering time-impulse or other types of measurements between plant and remote pump location.

For data transmitting, controlling, indicating and recording, there exists on the market today a variety of telemetering systems. Most of these are reliable and have been time tested; so it becomes a matter of personal preference when the designer chooses time impulse, tone, balanced bridge frequency shift or pneumatic system.

Comparer Units

Instruments for indicating, recording or totalizing almost any sensed data are already on the market and have been in use for many years. These devices are capable of being used to compare the data with set limits and of transmitting the deviation from those limits a short distance back to the control devices. Transmission can be by any of the methods mentioned but pneumatic, electric or electronic are to be preferred. Such data as flow, flow ratios (Fig. 4), level, pressure, concentration of chem-

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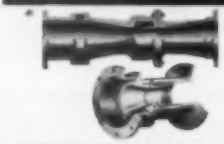

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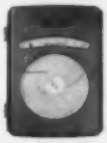

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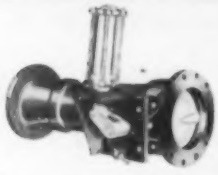
CONTROLS



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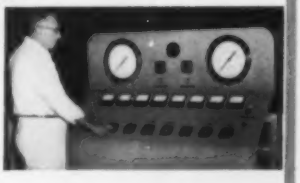

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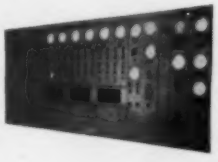

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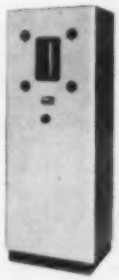

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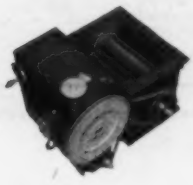

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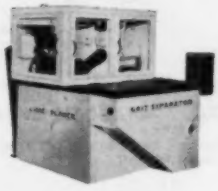

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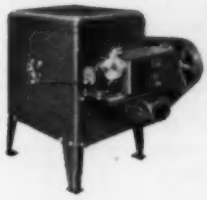

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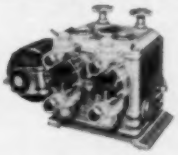

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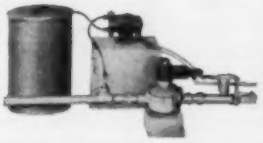
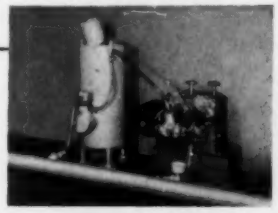
Deluxe chemical proportioning pump for caustics, acids, slurries, etc. Features feed rate adjustment while in operation. Simplex, duplex (shown), and triplex models — feed rates 0.2 to 57 GPH for discharge pressures to 125 psig. "See-thru" reagent end gives visual check on pump operation. Bulletin 1225-1.



AUTOMATIC/PROPORTIONAL CHEM-O-FEEDER

Powered by the flow through the pipe line, this efficient feeder controls chemical feed in proportion to main line flow. Paced by standard main line, bypass, or fire line meters. Capacities 0 to 5 GPH against 4 to 100 psig. pressures. Bulletin 1260-2.



FLUSH FEEDER (Patent Applied For)

For controlled feeding of slurries of thin mudlike consistency or corrosive chemicals. Unique check valve assembly mounted directly on slurry tank handles slurry . . . metering pump handles nothing but flushing fluid. Provides positive slurry flows. Reduces need for frequent slurry make-up and reduces tank costs. Send for details.

Send for product Bulletins, or comprehensive Bulletin B-I-F 6. Proportioneers, Inc., 376 Harris Avenue, Providence 1, Rhode Island.

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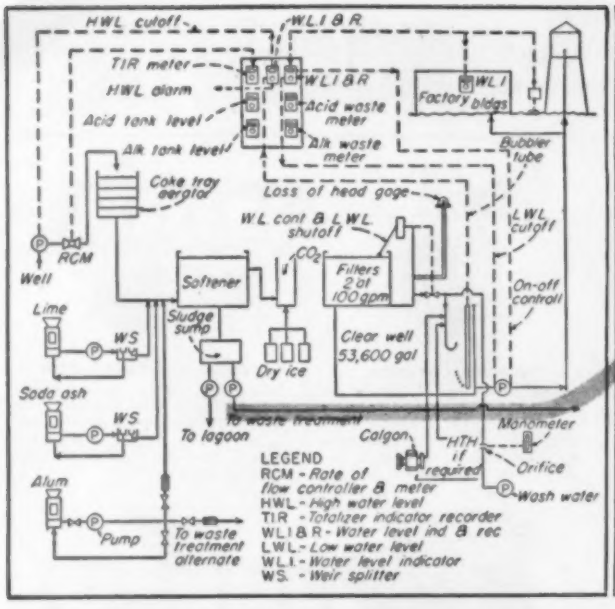

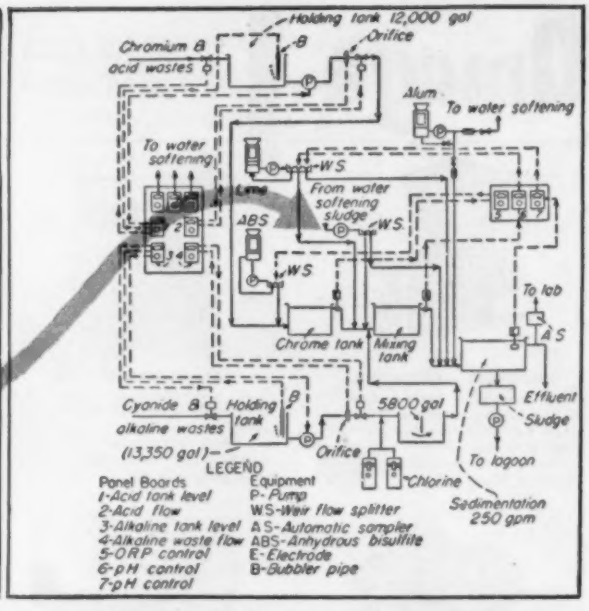

Fig. 6—DIAGRAM of industrial water softening control system **Fig. 7—DIAGRAM of industrial waste treatment system**

Note: Sludge from water softening is added to waste treatment for pH adjustment
(Diagram courtesy **Eng. News Record**)

ical characteristic, conductivity, oxidation-reduction potential, etc., can be handled by devices currently in use either in the sanitary engineering field or in the chemical process field. The adaptation of digital or analog computers to function as part of the comparer unit is quite possible, being used today in the process industries.

Control Devices

The necessary control units for automatic operation exist today. They include pumps, valves, chemical feeders (solids, liquid, gas), etc., all of which are in common use. Pumps, particularly centrifugal and gear pumps, with magnetic or variable speed drive, are ideally suited to complete automatic operation. Valves (particularly butterfly) operated by hydraulic, pneumatic or electric operators, lend themselves perfectly to the control of flow and level in automatic water and waste-water treatment.

Probably one of the best known control devices of automatic operation in water and waste-water treatment is the chemical feeder. Chemical feeders are divided into three types: Solids feeders, liquid feeders and gas feeders. Solids feeders may feed either on a volumetric basis or on a gravimetric basis. Gravimetric feeders may be either loss-in-weight or belt gravimetric types; liquid feeders may be volumetric feeders including decant types or positive displacement feeders including the Archimedes wheel (Rotodip) or loss-in-weight feeders, and the proportioning pump, either diaphragm or piston. Gas chemical feeders usually operate on the basis of volume measurement through an orifice under controlled conditions.

Dry Feeders

If automatic operation does not require a high degree of accuracy in rate of feed, volumetric feeders for liquids and solids may be satisfactory. On the other hand, if automatic operation requires chemical dosage to be as accurate as possible, the more accurate continuous loss-in-weight gravimetric feeders should be used.

A description of the loss-in-weight feeder as a control device will show how the unit fits into fully automatic control. This chemical feeder consists basically of a storage hopper containing several hours' or several days' supply of chemical. The hopper is mounted on scales and is counterbalanced by a scale beam and a counterpoise. Constant or variable speed drive means are provided to continuously retract the counterpoise by a lead screw. A feeder device and controller complete the assembly.

The desired rate of feed is obtained by adjustment of the rate of counterpoise retraction on the scale beam. An internal control loop is established, consisting of a scale beam, controller, and feeding mechanism, whose collective operation is to compare the instantaneous position of the scale beam against a reference point and to cause a loss in weight of material from the hopper. Thus, the controller actuates the feeder mechanism to feed out the proper amount of chemical continuously. The hopper is reloaded periodically as required. For high rates and continuous feed a twin hoppered feeder is available, one hopper of which unloads while the other is being filled at the same rate from storage.

This feeder can be made proportionally responsive to liquid flow rates in a plant when this flow is translated into terms of potential difference or a pneumatic pressure. The addition of pneumatic or electric positioners on the variable speed drive retracting the counterpoise will permit the control of the feed rate in response to the flow variable. Similarly, control of rate of feed from the measurement of some chemical characteristic in the water or sewage is possible when a sensing device is available to determine the desired characteristic such as pH, conductivity, ORP, etc. and convert that sensed data into electric, electronic or pneumatic values which can be transmitted back to the feeder lead screw drive.

Using a similar type of feeder and one of several available feeding devices, for example a gear pump driven by variable speed motors, permits liquid of any viscosity to be fed on a loss-in-weight basis in response to conditions of flow and chemical or physical characteristic of the liquid undergoing treatment.

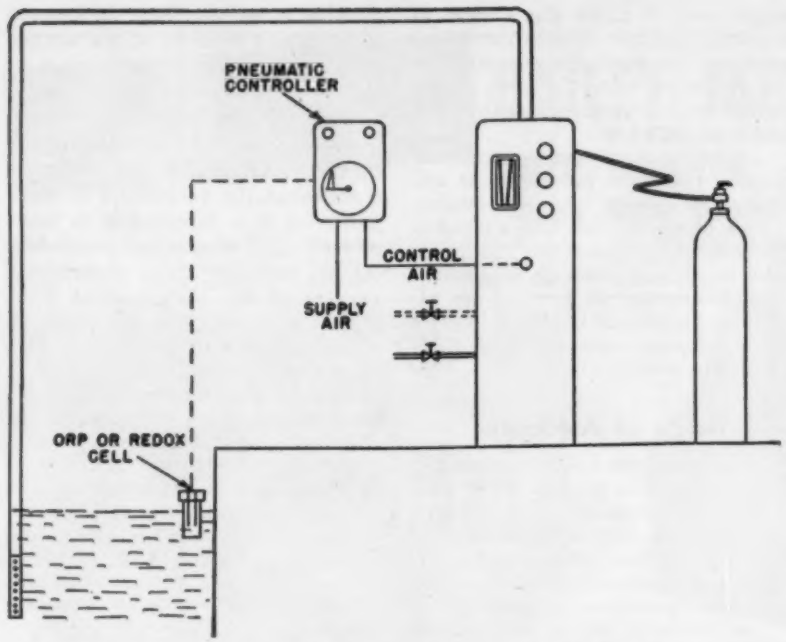

Fig. 8.—DIAGRAM of automatic chlorine feeder control

Proportioning Pumps

Solutions of coagulants, fluorides, softening chemicals, etc. can be fed by solution feeders of all types and automated solution feeding for clarification, sterilizing, softening, stabilizing or corrosion control is even now becoming more common with large water supplies. The primary sensing instruments are pH and Redox and conductivity meters, sometimes in combination with flow meters. The comparatively stable conditions and large chemical capacities in most water supply systems do not normally require extremely accurate solution feeders except as a convenience in materials handling and to give more accurate inventory of chemicals used. But it must be remembered that control of chemical dosage means economy of operation. Automation, with an end-point control, calls for a regulating device rather than a metering device in handling solutions.

In the case of industrial waste treatment the control problem is so difficult that the simple regulating device, such as a valve, swing pipe decanter, conveyor, etc., may not be satisfactory. To neutralize and clarify waste products from process plants may well require a high retention factor, automatic control by a primary element and a metering device for the final control element. The process load in waste treating can vary over such wide limits that stable automatic control is virtually impossible. Measuring and control lags and wide capacity variations can often be minimized by use of a more accurate final element whose response rate can be accurately predicted.

As an example, the solution requirement for acid waste neutralization would be the product of the pH and the flow. At certain operating levels in the plant due to seasonal or work shift changes the range of variation in these factors might change in a predictable way. A very difficult control problem can be simplified by using a holding tank to equalize flow and concentration. In lieu of this arrangement, a solution feeder can be used whose response range can be shifted. Thus flow and pH can be integrated and used to regulate the speed of a final element such as a proportioning pump, the anticipated range of variation can be set by changes in stroke length so that overall response becomes far more uniform.

A proportioning pump in itself can be used as an integrating device wherein flow controls the speed of the pump and pH controls the stroke length.

This type of operation involves very wide variation in solution rates at comparatively low levels, from many gallons to fractions of a gallon per minute. These conditions are fairly typical in industrial waste treatment. Water supplies generally have a more uniform, high level demand for treating chemicals and solution feeding is not the usual approach at present but may become more general in the future if Mr. Rogers' prognostications hold true.

Today's Applications

As might be expected, the first unit process in sanitary engineering to come under automatic control was that of pumping. Control of pump operation has long been possible from the level in reservoirs or pressure in elevated tanks, with start-stop operation in accord with the sensed condition in reservoir or distribution system. (See Fig. 5)

An advance in automatic pump operation came with the introduction of the Pressureflo Control System whereby the pump operation on a distribution system was started and stopped according to the demand for both flow and pressure. This combination of pressure and flow as the controlling information assured customers that their requirements would be satisfied at all times. In connection with this automatic operation of pumps, it has been possible to set up sequencing cycles so that where multiple pump installations exist, each pump is operated in turn and for time periods that insure equal wear on the individual units.

Semi-automatic operation of chemical feeders and other auxiliary equipment has been successfully practiced for many years, particularly where it has been desirable to pace the chemical feed rate proportionally to the flow of liquid being treated. (See Fig. 6 & 7) Step and program time-cycle controls have also been used for chemical treatment.

An approach to the automatic plant came within recent years when the operation of a whole water treatment plant was started and stopped according to the level of water in the elevated storage tank. In this case, well pumps, aerators, lime softening, sedimentation, filtration, fluoridation and chlorination started and operated as an integrated plant on a signal from a low water level in the elevated storage tank and operations stopped on a high water level signal. This is not a true automatic plant, however, since an operator has to set the chemical dosage rates and backwash the filters.

Automatic operation of filters has been possible and in use for some time. One type of automatic filter control is Auto-Central® Control. With a minor adjustment in this equipment, it is possible to have filters cut out of service when the loss of head reaches the maximum allowable and thereafter to be put through a washing cycle (including two washing rates) for time-cycle controlled peri-

ods of washing, and to be returned to service when the washing cycle is completed. Installations of the "Auto-Central" Control System use a warning system to advise the operator when the filter is ready to be washed and he, in turn, pushes a button which initiates the washing cycle. It is easy, however, to bypass the operator entirely and wash the filters automatically. There are other automatic filter control systems.

Automatic control of alum feeders from the turbidity of the settled water is now in use in a plant in California. Several automatic turbidity measuring and recording devices are now available and need only refinements to make them fully acceptable for complete control of coagulation or softening on the basis of turbidity and flow.

Automatic control of gas chlorine feeders from a continuous determination of the residual chlorine is now in use in several locations. This system of control has been used in both water and sewage treatment. Control of oxidation-reduction reactions, e.g. the reduction of hexavalent chromium or the oxidation of cyanides, is entirely feasible and is now in use based on the oxidation-reduction potential. (ORP or Redox—Fig. 8) Some studies have been made of the importance of ORP in sewage treatment processes and these offer highly interesting speculation as to the possibility of putting the Redox potentiometer to use in the control of sewage treatment processes.

Control of fluoride addition is currently being done by conductivity measurements of the water before and after addition of the fluoride chemical, and studies are now being made on the use of conductivity measurements in the control of coagulation.

Control of acid neutralization from continuous pH recording cells is common-place in many industrial waste treatment installations of that type. In all of these cases of automatic control, present day devices for flow measurement are used as an integral part of the control system. In the activated sludge process, for example, ratios of air to sewage and of return sludge to sewage are now being sensed by flow meters and the ratio calculated by analog devices which transmit the data on ratio to gauges in the central control station where the operator can adjust either flow to obtain the ratio he wishes. It is a simple step to adapt this system to automatic control wherein the actual ratio can be constantly compared to the desired ratio and the flows change automatically by signal from the computor device.

As indicated previously, remote supervisory control including the operation of pumps, chemical feeders, valves, filters, etc., has been applied in numerous locations in this country as well as abroad. Thus it is apparent that automation in some of its aspects is already an important part of the functioning water or waste-water treatment works.

Future of Automation

Obviously, not every manufacturing or treatment process can become completely automatic in the strictest sense. In the field of sanitary engineering, however, automation is more than just a possibility. It is on its way to becoming an accomplished fact.

In discussing the subject of automatic operation before the Pennsylvania Water Works Assn. in October 1955, Harry E. Jordan, Secretary of the Amer. Water Works Assn. said: "The 'fear-complex' appears to affect the attitude of some water works engineers and operators in considering the application of certain modern inventions to the operation of water works equipment." Then Mr. Jordan recounted a number of automation applications in water works much as outlined above, except that he gave specific locations.

Mr. Jordan continued: "Supervisory control of automation of water works installations is growing so rapidly and so convincingly that it appears to the writer that any sizeable program, presently in the planning or drafting room stage, must give consideration to the extent of automatic control or automatic recording of information that would improve the operation of the system."

Part of the "fear complex" about automation in this field as well as in others is the fear that machines will replace manpower and that automation costs too much. It is true that automation to some extent does and will reduce manpower required but that is not the essential reason for adopting automation. On this point, Mr. Jordan commented in these words: "Let it be said at this moment that the objective in the writer's thinking is not to reduce the amount of manpower required to operate the water works system. Rather, it is to improve the service to the public through the supplementation of manpower by modern mechanical and electrical equipment . . . Automation is not essentially a substitute for manpower—it is a supplement to manpower. . . ." Regarding costs, Mr. Jordan said: "A rather obvious answer to all this chatter about automation is that it costs too much. A simple rejoinder is that human mistakes cost too much."

There is no doubt that Mr. Jordan's ideas will come to prevail and that automation will become more and more important to the field of sanitary engineering. We may expect to see the application of automation advance most rapidly in the areas where it is already established, such as pump control, flow control, filter operation, chlorination and chemical treatment involving neutralizing and oxidation-reduction reaction.

We may expect perhaps slower but still certain advances in the control of chemical treatment involving processes utilizing chemical reactions, e.g. coagulation, softening and iron removal. We may expect even slower advances in the control of biochemical oxidation, sludge digestion, etc., not only because of the necessity of developing adequate sensing elements but because enzymatic and biological reactions are still not fully understood. That new sensing devices will be developed, the authors do not doubt, but unfortunately our crystal ball does not indicate how soon. We do know, however, that we have already climbed part way up the stairway of automation and it appears that we may reach the top in the not too distant future.

Acknowledgment

The writers are indebted to M. E. Rogers and W. H. Brown of Builders-Providence, Inc. for their ideas on the plants of tomorrow; to A. A. Melnychuk, Chemical Engineer, Omega Machine Co. for information on solids feeders; to J. R. Hefler, Research Engineer, Proportioneers, Inc. for information on proportioning pumps, and to Dr. George E. Symons, Consultant & Technical Editor, for editorial assistance in the preparation of this article.

METERS : GAGES : CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

WATER & WASTE TREATMENT DIVISION

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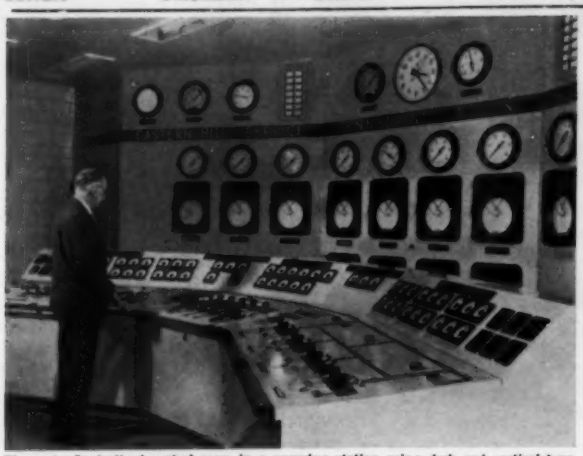


Figure 1—Centralized control room in a pumping station using desk and vertical-type panels.

CENTRALIZED CONTROL

The use of centralized control rooms in water supply and sewage treatment plants helps designers to secure fully co-ordinated operation and greatly reduced man-power requirements. When planning centralized control installations you now have available a line of Bailey products developed especially for this service. These products which are described in Bulletin 17 include:

1. Bailey Pneumatic and Electric Transmitters.
2. Bailey Receiver-Recorders and Indicators.
3. Bailey Pneumatic Control Components.
4. Bailey ARMORTUBE Cable for carrying Pnuematic Signals.

TELEMETERING SYSTEMS

Figure 2—Bailey Receiver-Recorder for pneumatic and/or electric signals.

Pneumatic and/or electric signals actuate Bailey Telemetering Systems. Either or both may be received in the Type WM55 Receiver-Recorder (Product Specification E12-5). Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized on one record. Automatic control may also be part of the measuring and telemetering system.

For a complete list of factors such as flow, level, pressure, temperature, pH, conductivity, turbidity and speed which can be measured and telemetered, ask for Bulletin 17.

CHEMICAL FEEDERS

Electric or pneumatic signals from Bailey Registers may actuate chemical feeders, fluid sampling devices, alarms, or pump controls.

BAILEY REGISTERS

Figure 3—Mechanically operated register.

Bailey Registers measure flow of sewage, industrial waste, sludge, dirty water or other liquids in open channels or in pipelines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs and other factors.

Pneumatic and/or electric signals established by Bailey Registers may actuate automatic control systems.

Figure 4—Bailey Filter Operating Panels of the indicating type.

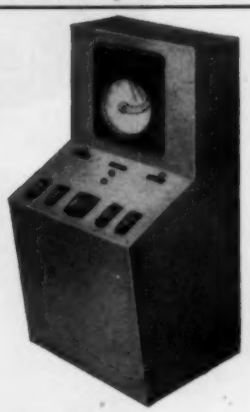


Figure 5—Bailey Filter Operating Panels of the recording type.

The following are typical applications:

. . . FOR OPEN CHANNELS

The Bailey Flume or Weir Meter is simple and accurate. It consists of a single float connected by a flexible cable to a sturdy indicating, recording and integrating mechanism, which may be mounted on a panel board, a wall or a column. Remote location may be obtained by the use of a Bailey Telemetering System. Ask for Bulletin M22-5.

. . . FOR PIPELINES

The Bailey Fluid Meter accurately measures flow of steam, liquids, and gases in pipelines at high or low pressures. A venturi tube, flow nozzle or orifice is used as the differential producing device and the meter indicates, records and integrates on a standard Bailey Register. This meter may also provide records of pressure, temperature or liquid level on the same chart. Ask for Bulletin 301.

. . . FOR LIQUID LEVEL

Bailey Registers may be used in measuring liquid level in open tanks and reservoirs. Three methods are available:

Open Float Method—For location above liquid level.

Static Pressure Method—For location below liquid level.

Bubbler System—For measuring level or specific gravity of corrosive liquids and for liquids with solids in suspension. For more information on Bailey Level Recorders ask for Bulletin 17.

. . . FOR AIR FLOW

Bailey Air Meters measure air flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the standard Bailey Fluid Meter and is designed to operate on a maximum differential pressure of 8" of water.

Air flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder measuring blower shaft speed by means of an electric tachometer. This may be calibrated to record in terms of air flow.

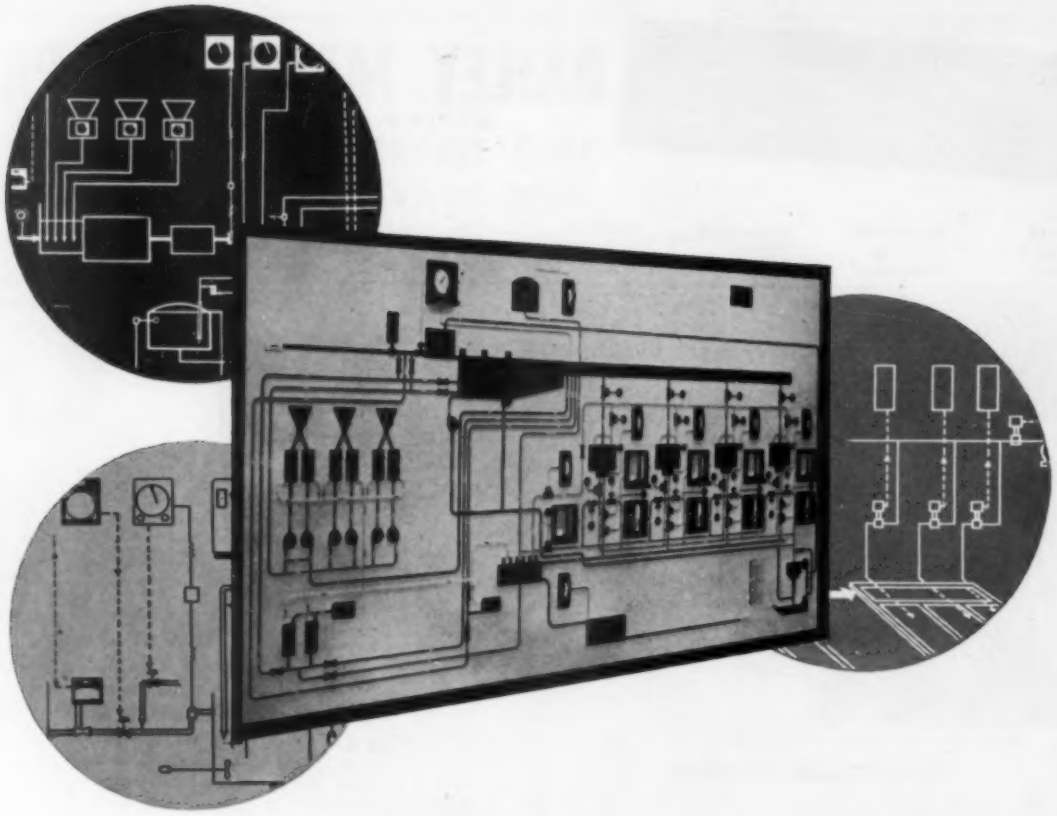
. . . FOR RATE CONTROL

The Bailey Rate Control System is designed to meet the specific requirements of each application. It operates at peak efficiency on either filter backwash, filter effluent, or filter surface sand wash system. Meter differentials available from 12.5 to 1200 in. of water.

ARMORTUBE CABLE

Figure 6—Bailey ARMORTUBE Cable.

This protected multitube cable for pneumatic transmission lines minimizes installation costs and provides inherent hazard-proof protection for control systems. It is stocked in three sizes of 4, 8 and 12—¼" O.D. copper or aluminum tubes encased in heavy rust-resistant galvanized steel strip. Ask for Bulletin G91-9.



in water, waste, and sewage treatment . . .

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Complete Process Instrumentation

Recording Instrumentation in Water Works

by OSCAR GULLANS

Chief Water Chem. Engr., South Dist. Filtration Plant, Chicago, Ill.

THE OPERATION of Chicago's South District Filtration Plant, which is presently considered the world's largest water treatment plant, depends to a great extent on the 352 primary measuring and recording units with which the plant is equipped. These instruments are essential in the control of water basin and tank levels, pumpage rates, and chemical dosage; in the study of operating efficiency; and in preparing consolidated operating and technical reports. They provide a graphic, up-to-the-minute record of operating phases and frequently reveal unusual conditions which can be quickly traced and corrected. They gather information automatically and continuously 24 hr a day without the presence of a human operator. In short, they supply the data which lead to better service, greater safety, and more economical operation.

In the South District plant, recording instruments are required to operate under conditions of dampness, vibration, extremes of heat and cold and in corrosive atmosphere; yet, as permanent equipment, they are expected to last for a period comparable to that of the heavy apparatus with which they are used. Accordingly, the instruments used are required to have maximum practical accuracy and flexibility in combination with ruggedness and simplicity.

In a large water plant it is essential that the recording units of certain critical instruments be located where they can be observed continuously by the operating personnel concerned. At the South District plant, a centrally located control panel equipped with 30 automatic recorders, as shown in Fig. 1, is used. These recording units are actuated by pneumatic or electric integrating and recording transmitters located at each important phase in the plant's operation. The control panel is manned by competent engineers 24 hr a day and serves as the nerve center for all plant operations.

All essential recording instruments can operate on emergency power. Whenever the "house" current is interrupted, the emergency generator and storage battery circuits automatically cut in to keep the instruments in operation. This provision is particularly important in the control of water levels, chemical feeds, and residual chlorine. Although only a few of the many recorders in use throughout the plant will be discussed here, most of those critical instruments on the control panel, which might be called the operating group, will be described.

Water Level Recorders

Among the most essential instrument groups on the panel is the set of water level recorders. The transmitters of these are actuated by pneumatic equipment with impulses transmitted electrically to the recorder. Most of the transmitters require a constant source of compressed air as well as electricity; some, however, are located to permit operation by direct water pressure from the tank or basin. The control of pumpage rates and water levels at this plant assumes greater importance when it is noted that summer peak loads require nearly twice the normal rated capacity. Since no elevated storage is provided in the system, it is necessary that production equal consumption at all times. Accordingly, the plant operates within extremely close water level tolerances, and a single wrong move can cause the filtered-water reservoir to overflow or flood out other portions of the plant.

Eight essential recorders (indicating the water levels of the pump suction header, pump discharge header, settling basins, and filtered-water reservoirs) supply the control engineer with a continuous visual record of the status of each unit. These recorders indicate not only when it is necessary to adjust pumpage rates, but also any unusual condition that may develop. As a typical example: At 8 PM on Jul. 31, 1949, the control engineer observed a sudden rise —at the rate of 1 ft in 10 min—in the level of the filtered-water reservoir, as indicated by the elevation gage shown in Fig. 2. (The reservoir is operated within limits of 1½ ft of maximum or minimum levels.) A hurried call to the filter operators revealed that the compressed-air supply had apparently failed and that the filters under automatic control were completely open. The filtration engineer and filter operators succeeded in shutting off those filters quickly, and had matters under control by the time the reservoir reached a level within 6 in. of overflowing. The urgency of the accident was compounded by the fact that it happened at a time when the plant was supplying water at nearly the peak rate.

The experience gained from this mishap led to swift remedial action. An auxiliary compressed-air tank of 100 cu ft capacity was installed to serve each group of twenty filters. These tanks normally function as part of the regular compressed-air system, which operates at 100 psi; if the pressure drops below 80 psi an automatic valve closes the supply from the compressor and retains the pressure in the tanks until the supply pressure is again normal. The auxiliary air thus provided is sufficient to operate filter controls for a period of 2 hr or longer, which is time enough to set up the manual filter controls, or to place a small emergency steam-driven compressor in service on the line. The plant also possesses a portable gasoline-powered air compressor which can be connected to the compressed-air line at several points.

A second precautionary measure was to initiate regular periodic tests of all filter controls. Normally, if air pressure fails, the filter controls are designed to hold the filter at its current operating rate, rather than to permit the effluent control valve to open wide. At the time of the near-flood condition, however, these controls failed to operate on 75 per cent of the filters, due to lack of proper maintenance. It is now standard practice for an operator to trip these controls at least once each week in addition to current preventive mainte-

* Reprinted from Jour. AWWA Vol. 48, No. 5, p. 525 (1956)

nance, to make sure that they are operating properly. Subsequent tests of the compressed-air system indicated the filter controls to be running perfectly.

As an additional safeguard, red warning lights have been installed on the control panel beside each recorder; these turn on automatically as soon as the water level comes within half a foot of maximum safe level. A warning bell rings when the pressure of the plant's compressed-air system falls below 80 psi.

Further difficulty was experienced with these transmitters when they were equipped with oil bubblers used as air flow indicators. Some oil eventually reached the contact switches, necessitating frequent maintenance. In addition, the small needle valves controlling the air supply frequently became fouled. These conditions were partially corrected by replacing the oil bubbler cups with small rotameter-type air flow indicators, using a light plastic ball instead of a rotor. The needle valves on the air supply line were replaced by a larger type of regulating valve, to compensate for increased wear. This type of air flow indicator has given excellent service for many years, and requires little or no maintenance.

A second maintenance factor, which applies to all pneumatic controls or air-operated instruments, is the need for clean, dry compressed air. This was provided by the installation of an electric dryer and an oil filter unit. Though the filter unit was originally designed for glass wool filter pads, these have since been replaced with cellulose fiber pads, which are more efficient in removing fine particles of oil carried with the compressed air. All these changes have reduced maintenance on the water level recorders by 75 per cent.

Residual Chlorine Recorders

Another important set of recording instruments is the group of seven residual chlorine recorders. These are also located on the central control panel, where they are under continuous observation by the control engineer. All deviations or deflections of the recorders, including those caused by normal dosage changes, are immediately reflected on the recording charts. This kind of surveillance assures adequate chlorination of the water in its progress through the plant, and particularly at the plant outlet. The charts in Fig. 3 present a graphic illustration of a series of typical changes.

Chart 3*a* indicates a sharp drop in chlorine feed between 11:00 and 11:30 A.M. The recorder is connected to a sampling line from the point at which the water enters the first mixing basin, approximately 4 min after the chlorine has been added.

Chart 3*b* indicates the chlorine residual at the entrance to the settling basin, 30 min later. On this chart, it will be observed, striking deviations caused by the sharp drop in chlorine feed have been tempered somewhat by dilution.

Chart 3*c* is from the residual chlorine recorder at the end of the settling basin, approximately 1½ hr later. Here the dip in the curve is still quite pronounced.

Chart 3*d* is from the recording unit which indicates the chlorine residual at the entrance to the filtered water reservoir. At this point the residual had only dropped to 0.6 ppm, which was not below the minimum standard. It was not necessary, therefore, to apply additional chlorine at the outlet shaft.

There have been numerous occasions when such an interruption in the chlorine feed, immediately indicated on the recorder charts, resulted in effective remedial action before the water left the plant. Additional chlorine may be applied at the filtered-filtered-water reservoir), and at the water header (the entrance to the outlet shaft, which is the final point of chlorination. In any case, if the recorder chart indicates an approach to a minimum residual at the outlet shaft, additional chlorine can be applied at that point at a few minutes notice. Thus, the recorder charts act as "watchdogs" for the entire chlorination process. Because of the satisfactory operation of these recorders, the same type has been installed in the pumping stations, both in the area supplied by the filtration plant, and in the areas in which chlorination is performed at the pumping station itself.

Sand Expansion Recorders

A recording instrument seen in few water plants is the sand expansion recorder for filters. These air-operated gages provide a simple and instantaneous means of indicating and recording the exact position of the surface of the sand in a filter bed during washing. The system consists essentially of two parts—the transmitter, mounted on a beam over the filter bed; and a receiver, mounted on the filter operating table, in the same cabinet as the loss-of-head and rate-of-flow recorder.

The transmitter consists of a diaphragm housing, supporting a lightweight cone which rests on the surface of the sand. Lightweight tubing connects the cone with a counterweighted beam arm above water level. The beam arm is actuated by the tendency of the cone to float at the surface of the sand during washing. The beam arm operates the transmitter by means of an air flapper and air bleeder valve with bellows. Air pressure from these bellows also actuates the receivers. The transmitter is primarily a heavy-duty precision pressure gage containing a flow actuator, linkages, and a chart calibrated in the

Fig. 1. CENTRAL Control Panel, South District Filtration Plant

The panel, located in the control engineer's office, is equipped with 30 automatic recording units connected by electric and pneumatic transmitters to instruments at each important step in the plant's operations.

desired units. (It is interesting to note that sand, when in suspension in water, exerts sufficient pressure to raise a light float that will maintain a position at the surface of the sand when expanded in backwashing.) The instruments can be easily cleaned, and may be adjusted by manipulation of the counterweights and linkages.

In operating the filters at the South District plant it is attempted to maintain a backwash rate which will produce a sand expansion of 3½-4 in. This may seem somewhat low, but with 0.65-mm sand, experience has shown that this expansion is sufficient for thorough backwashing. Because the water temperature at the South District plant varies between 32 and 72°F, it is necessary to adjust backwash rates accordingly. At 32°F, the backwash rate for each filter is normally 25-26 mgd, while at 72°F as much as 34-35 mgd may be required.

Observation of the sand expansion chart quickly indicates current backwash conditions. As the chart is operated by an automatic time clock which rotates only while the backwash is in operation, the recorder indicates the exact duration of the backwash as well as the record of sand expansion. A single chart is normally sufficient for recording the filter washes for 7 days. With this type of control the chart indicates any unusual conditions which might be detrimental to the filters, such as overexpansion of a sand bed, short washing period, or incomplete closing of the wash valve. The float unit does not seem to be affected by the surface wash system.

Figure 4 is a composite chart from the surface wash recorder on Filter 31. Section 1 indicates a long wash period (about 6 min) with only 3 in. of sand expansion, probably due to a low level of the wash-water tank. Section 2 indicates a slow opening of the backwash valve; Section 3, a slow closing. Sections 4 and 7 are typical of a normal filter wash of 2-3 min. Section 5 indicates that the operator closed the backwash valve instead of the surface-wash valve. Section 6 is a typical indication of the start of backwashing on another filter while the wash is still in progress on the filter to which the chart applies.

These recorders require very little maintenance. An occasional oiling and cleaning of the linkages serves to keep them in smooth operating condition. As clean dry air is used in the South District plant, the input control orifice seldom needs to be cleaned. Flexible rubber air connections require occasional replacements, and the South District plant considers synthetic tubing more satisfactory for its purposes.* Installation of these sand expansion recorders on each of the plant's filters has proved a sound investment.

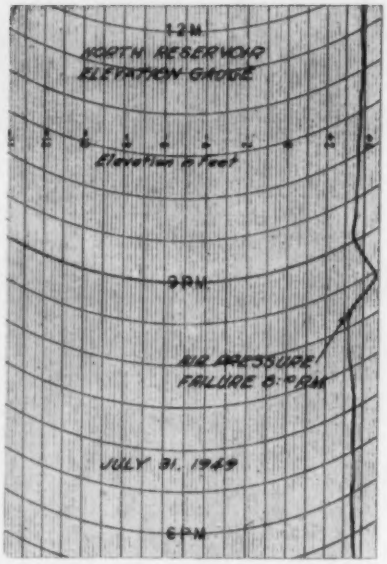


Fig. 2. WATER Level Recorder Chart

The chart shows surface elevation changes in the North Filtered-Water Reservoir on Jul. 31, 1949. The major deflection indicates a sudden rise.

Filter Controls

The filter loss-of-head and rate-of-flow recorders are standard units equipped with air transmitters. The rate of flow is measured by the differential pressure from the venturi tube, which actuates the diaphragm chamber to one side of the transmitter unit. Compressed air at a reduced pressure (2½-15 psi) operates the transmitter through an input-restricting orifice. The variable pressures are in turn transmitted to the recording chart on the filter operating table. The loss of head is measured by static pressure maintained across the upper and effluent section of the filter.

Within 2 years after these instruments were installed it was necessary to replace all the steel attachments with stainless steel hardware, because of rusting and corrosion due to dampness in the air. This was also required on the transmitter units on the loss-of-head and rate-of-flow recorders. The plastic mercury wells on these units began to crack after about 5 years of operation. This is believed to be due to the method of attaching the wells to the holders; and the screw locks presently used for that purpose are being replaced by metal ring clamps.

Dehumidification equipment was installed in the filter pipe galleries in 1950 to reduce exterior corrosion of instruments and filter equipment. Humidity is now maintained at less than 50 per cent at all times, regardless of temperature, and condensation has been completely eliminated. It is estimated that this equipment has already more than paid for itself in reduced maintenance costs.

The air supply used in these air-operated instruments should be absolutely clean and without free moisture. The importance of this is evident from the fact that the input-restricting orifice measures only 0.007 in. in diameter. Pressure in excess of 5 psi above the required operating level should be available.

For small installations, if there is no air available from a compressed-air header, a small compressor of the diaphragm type works very well, with adequate controls. The supply should first be passed through an effective air cleaner to remove dirt and moisture, then through a reliable pressure-reducing valve and a sufficient length of metal tubing to allow the expanded air to assume room temperature before entering the instruments.

For larger installations, in which the air supply comes from a compressed air main, it is best to feed the air through a pressure tank which can serve to collect oil and water globules or even scale accumulated in the air main. An additional air dryer and cleaner should be used in the line after pressure reduction. When the header supply fluctuates in pressure, pulsation may be eliminated by using two pressure-reducing valves in series, setting the first valve midway between the high and low pressures. Copper refrigeration tubing is recommended for most piping connections as it is flexible, free of internal scaling, and less subject to leaks. Only globe or globe needle valves packed for air service should be used.

Flowmeters

Another important recording instrument of the flowmeter type is the propeller-type indicator-totalizer-recorder meter located in the outlet shaft. This outlet meter is in continuous function recording the actual water output to the South District pumping stations. The water velocity actuates a six-bladed propeller, 33 in. in diameter, which is mounted in the center of a 16-ft diameter shaft, 82 ft below the surface. The propeller drives an enclosed vertical shaft to

*Tygon, a brand of synthetic corrosion-resisting tubing manufactured by US Stoneware Co., Akron, Ohio, is used.

the transmitter unit. The electric impulses are carried to a selsyn motor linked to a differential mechanism which operates the indicating and recording charts in the control room, half a mile distant. Impulses are also carried through the motor circuit to a calibrated totalizer in the recording unit. There is a totalizer at the transmitter, as well, which is geared directly to the propeller shaft and can be used to check the accuracy of the electrical transmitter and recorders. These instruments have given excellent service, and are accurate within 1.0 per cent, which is considered unusually good for such an installation.

Other instruments important to plant operations are the electric-load meter-recorders, wash water pumpage and tank level recorders, pH recorders, and the radioactivity monitor recorder. In a large water plant, it is necessary to maintain close control of electric power loads for the control of peak power-demand rates and lighting economy. Recording of filter wash water requirements is essential; including water for other plant requirements, the South District plant uses an average of 6.4 mgd. The pH recorders are necessary for corrosion control. The radioactivity monitor is equipped with a continuous recorder set up to indicate any such contamination as a part of the plant's civil defense activity.

In order to keep pace with modern improvements, the plant has purchased a magnetic flowmeter-recorder to fit a 20-in. pipeline. This instrument consists of a flow transmitter connected by electric cable to a dynalog receiver. Pneumatic or electric control as well as recorder or alarm accessories may be added to the dynalog instrument in the usual manner. An important advantage of this unit is its freedom from a number of the limitations of meters of the differential-pressure or restricted-area type. The pressure drop through the magnetic flowmeter tube is the same as it would be through a length of standard pipe, as there is nothing in the tube to obstruct the flow. By adjusting the instrument to read center scale for zero flow conditions, it will measure flow in either direction. The unit will be used for experimental purposes to determine its adaptability to larger pipe sizes. A unit of the same type has been used for some time for measuring flow rates on smaller lines (of up to 8-in. diameter). If this combination of flowmeter and recorder proves to be accurate at constant and variable flow rates, it may serve to eliminate some problems now encountered in operating high-rate filters with restricted effluent lines.

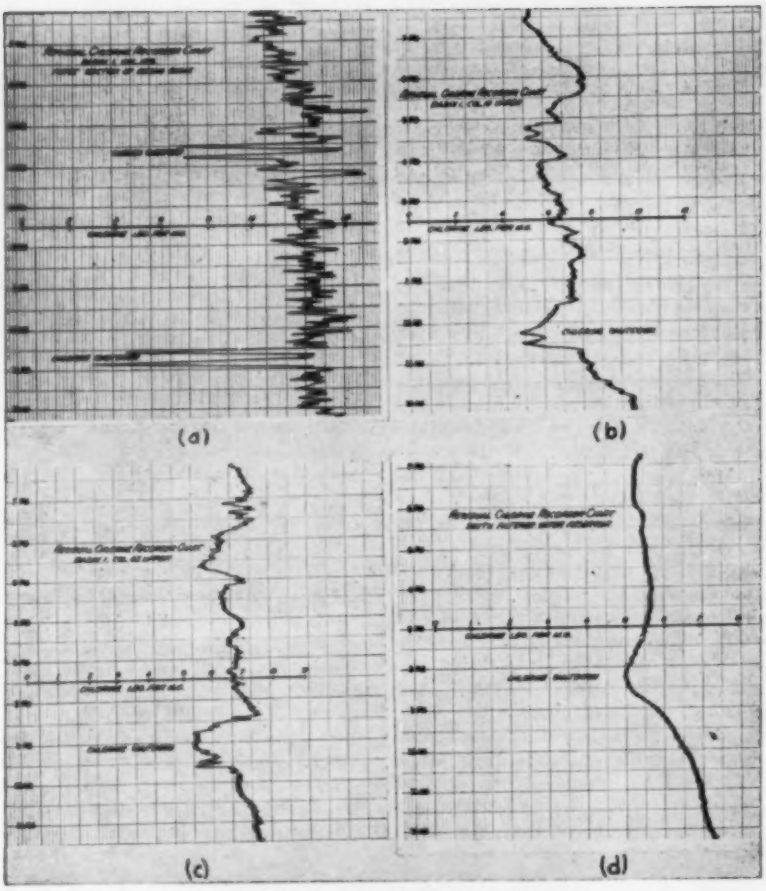


Fig. 3. RESIDUAL Chlorine Recorder Charts

The charts were made by recording instruments connected to sampling lines at various points in the plant's operations. Chart **a** is from the point at which water enters first mixing basin; Chart **b** from entrance to the settling basin; Chart **c** from output end of settling basin; Chart **d** from entrance to the filtered water reservoir.

Maintenance

Maintenance of all recording instruments is performed by a full-time electrician-mechanic who is specially trained for this service. There is, in addition, a team of technical engineers, whose primary function is to calibrate instruments and detect malfunctions. A preventive maintenance schedule is set up for all instruments, and all necessary repairs are recorded. This schedule assures inspection and maintenance of each instrument at specific intervals and has resulted in good performance with minimum replacements.

Automatic Controls

A look into the future shows that rapid advance is being made in adapting certain industrial instruments for water works use. Instrument manufacturers have developed automatic controls that require little attention, yet are rugged and reasonably foolproof. Wherever a specific action must be repeated for every increment of total flow or of the weight of a substance added to a process, integrating flowmeters using automatic sequence timing controls can be used. It must, of course, be possible to do the job mechanically, but it does not matter whether the substance flows continuously or is added in batches. In water treatment plants this sequence control is usually based on continuous flow. For measuring liquids and solids, there are a number of continuous-weighing and flow control systems commercially available. Instruments of this type have been in use for many years on automatic washing machines and industrial process-control equipment.

Some of the principles and methods of automatic control have already been adapted for the regulation of fluoridation equipment and similar types of chemical feeders. Many can be developed for use on existing equipment: indeed, electronic devices

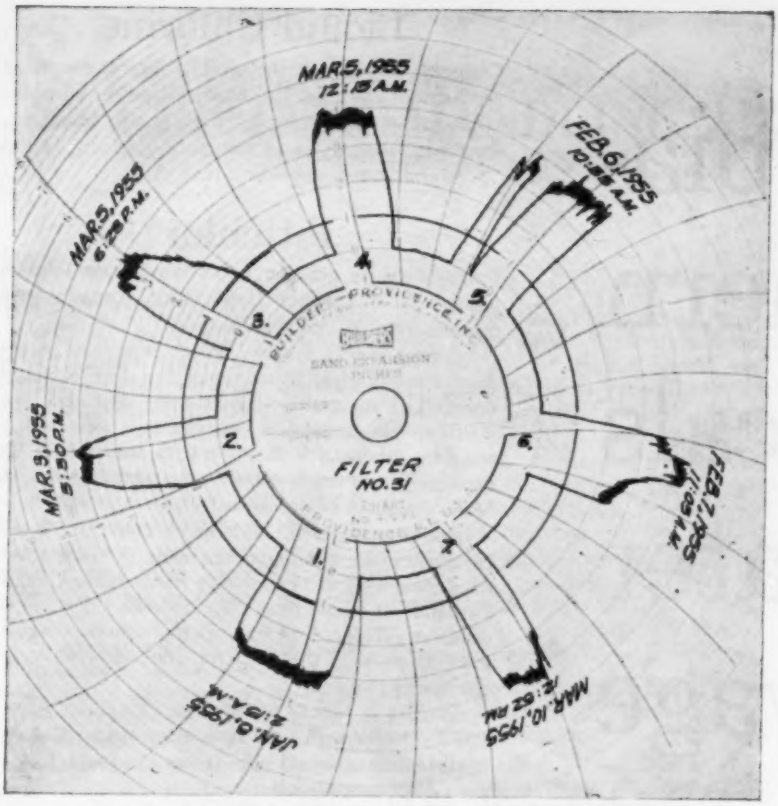


Fig. 4. COMPOSITE Chart From Sand Expansion Recorder

The numbered sections were each derived from a separate day's record from the surface wash unit on Filter 31. The chart is operated by an automatic time clock which rotates only during backwash.

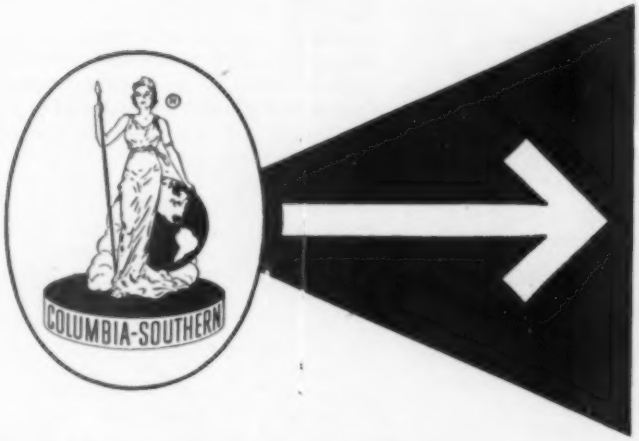
permit the addition of integrators, controls, and recorders without direct contact to existing equipment. The choice depends largely on the degree of automation desired, as continuous timer systems can be made either partially or completely automatic. Combinations of instruments and remote control devices now available are able (with sequence timing control) to perform the complete operation of shutting down, washing, and returning to service a rapid sand filter without human attention, recording all operations in the process.

Such instrumentation, when designed for maximum accuracy and flexibility together with ruggedness and simplicity, can provide the answer to a number of operating problems. The many automatic controls and recording instruments now on the market should be studied to determine whether they can be adapted for use in water works. Human operation is not always the most reliable: in water plants that operate around the clock, the incidence of human failure on night shifts is quite high. Accordingly, automatic controls and recording instruments should be considered when they will:

1. Reduce the danger of failure of treatment facilities
2. Aid the operators in performing their duties more efficiently
3. Reduce labor requirements
4. Assure management that operating procedures will be carried out as intended
5. Reduce plant maintenance costs
6. Improve and stabilize the quality of the filtered water.

Under the able leadership of John R. Baylis, Engineer of Water Purification, there are now seven experimental projects in progress at the South District Filtration Plant. Instrumentation plays an important part in many of these projects, and, as surveillance tests are completed and minor defects are discovered and removed, it is hoped they will prove of value to the water works industry.

Columbia-Southern chemicals for water and sewage treatment



Liquid Chlorine

Columbia-Southern is the world's largest merchant producer of chlorine. Its chlorine is produced under careful supervision to assure high purity. Shipments are made promptly in 15-ton multi-unit cars, and in 55, 30 and 16-ton single unit tank cars.

Pittchlor®

Pittchlor is a dry, granular, free-flowing, water soluble, highly stable Calcium Hypochlorite containing a minimum of 70% available chlorine.

In water supply systems, Pittchlor is used in the destruction of algae in reservoirs, the disinfection of distributing mains, the conditioning of filters, etc. Pittchlor's high stability also makes it an excellent stand-by product for emergency chlorination in the event of fire or flood, or when the water system has been contaminated accidentally.

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Pittchlor is packed for increased handling ease in 100 lb. drums with fully removable heads; also furnished in convenient 2½ lb. (6 per case) and 5 lb. (9 per case) resealable cans.

Light Soda Ash

Excellent for water treatment—free-flowing, rapidly soluble. It is a 99-100% Na_2CO_3 product with an Na_2O equivalent of more than 58%. Furnished in bulk cars or 100 lb. paper bags.

Caustic Soda

In *liquid* form, 50% and 73% concentrations. Shipped in 8,000 and 10,000 gallon tank cars. Also in 1,100 ton tank barges (50% only).

In *solid* form, tests 98-100% NaOH. Available in 100 lb. and 700 lb. drums.

In *flake* form, 98-100% NaOH. Available in 100 lb. and 400 lb. drums.

Pittabs®

Chlorine in dry, white, tablet form. Consists of Calcium Hypochlorite containing a minimum of 70% available chlorine.

Especially valuable in swimming pools because the tablets are slow dissolving and provide a continuous supply of available chlorine throughout an 18-hour cycle. Pittabs are excellent for uses in water and sewage works where the advantages of slow dissolving chlorine tablets are of value.

Pittabs are packed in 3 lb. and 7½ lb. resealable cans and in 100 lb. drums.

For further information on any of these products, please contact the Pittsburgh office or any of the branches.

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IN CANADA: Standard Chemical Limited and its Commercial Chemicals Division

CHEMICAL HANDLING AND FEEDING

THE COMMON water treatment process involving chemical treatment processes include algae control, coagulation, color removal, corrosion and scale control, chlorination, fluoridation, iron and manganese removal, pH adjustment, softening and taste and odor control. Less common treatment processes include silica activation, boiler water treatment, chlorine-ammonia treatment, dechlorination, defluoridation silica removal, slime control and ion-exchange regeneration.

In the treatment of sewage the most common chemical processes are chlorination for disinfection and odor control, sludge dewatering and coagulation, oxidation and reduction: neutralization may be required if the sewage contains certain types of industrial wastes.

Available Forms of Chemicals

There are more than fifty chemicals used for one reason or another in water or sewage treatment, many of which are used for special treatments. Dry chemicals come in various particle sizes (powder, ground, lump, rice, pellets, etc.) depending on the particular chemical and its intended use. Liquids, solutions and gases (usually liquefied under pressure) are other available forms of chemicals.

Characteristics of Chemicals

Most chemicals have distinctive appearances and properties. Among the important properties are toxicity, effect on skin, corrosiveness, and explosion or fire hazard, its activity in the presence of air or moisture. Bulk density of dry chemicals, commercial strength, and the solubility of chemicals are important factors in handling and feeding.

Handling and Storage

Unloading and storage facilities required depend on the chemical, its form, and intended use. Bulk chemicals may be transferred from railroad car or truck to storage by air conveyors, bucket elevators, direct dumping or shoveling. Packaged dry chemicals (bags, drums, barrels) are handled by hand or truck. Liquids, solutions, and liquefied gases each have their own particular methods of handling and storage.

Materials for handling of chemicals depend on the chemical, its condition, and its characteristics. In short, the nature of the chemical (dry, liquid, solution or gas) as well as it reactivity with other materials determines the material used for handling.

Chemical Feeders

Equipment for apportioning and adding chemicals to water or sewage is termed a chemical feeder. There are two basic types of dry feeders, volumetric and gravimetric. Volumetric feeders may be oscillating plate, oscillating throat, rotating disc, star feeder, screw feeder, ribbon feeder, or vibrating feeder. Gravimetric feeders may be continuous, semi-continuous, loss-in-weight, or any one of several miscellaneous types.

Solution feeders may be non-positive or positive displacement. Non-positive displacement solution feeders include decanters, orifice rotameter and crystal solution types. Positive displacement feeders include the rotating dipper and proportioning pumps.

Gas feeders operate on the principle that a gas flowing through an orifice causes a differential pressure which is related to the rate of flow of gas. There are three methods by which this principle can be applied. These methods include varying the pressure or vacuum upstream or down stream of the orifice, or varying the orifice itself.

Chlorine gas feeders are classified in several ways: (1) State of Chlorine, (2) basis of design features, and (3) methods of applying vacuum.

Miscellaneous chemical feeders include diaphragm pumps and Moyno pumps for feeding slurries of lime or activated carbon. Lime shakers and chemical feeders for activated silica solutions are also miscellaneous type feeders adapted from other standard type feeders.

Accessories required for dry chemical feeders include hopper agitators, dissolving chambers, bucket elevators, dust collectors, proportioning weirs, manifolds, gravimetric feeders, etc.

The selection of dry chemical feeders must consider such factors as operational requirements (feed rate, accuracy, records, type of control), storage requirements, location of installation, type of installation, type of feeder, and accessories. The selection of solution or slurry type feeders must also consider these same basic factors.

Feeding of Chemicals

Dosage of chemicals is the amount required to produce the desired reaction, expressed in terms of concentration of the chemical in the liquid being treated. Feed rate is the amount of chemical added to the liquid undergoing treatment, expressed in the rate of addition per unit time. Solution strength refers to the concentration of chemical in the solution as it is discharged into the liquid to be treated. The best method of expression of solution strength is in terms of pounds per gallon. (Use of per cent solution may be misleading unless the calculation is made properly).

The type of feeder, chemical solution strength, method of dissolving usually depends on the particular chemical being fed and the purpose of the treatment.

In the matter of operation of chemical feeders, control is important. Analysis is usually the basis of ultimate control of dosage and feed rate. Actual control may be by manual, semi-automatic or automatic systems. Operating control nomograms are often useful in calculating dosage.

Problems of operation arise in dry feeders from arching of chemicals, caking due to moisture, poor grade chemicals, impurities, variation in bulk density of the chemical, mechanical failures and other factors. Solution and gas feeders, too, are subject to operational difficulties for a variety of causes. Preventive maintenance, alert operators, good records, and regular factory service are the best means of reducing operating problems to a minimum.

Lime and Lime Slaking

by H. E. LORDLEY

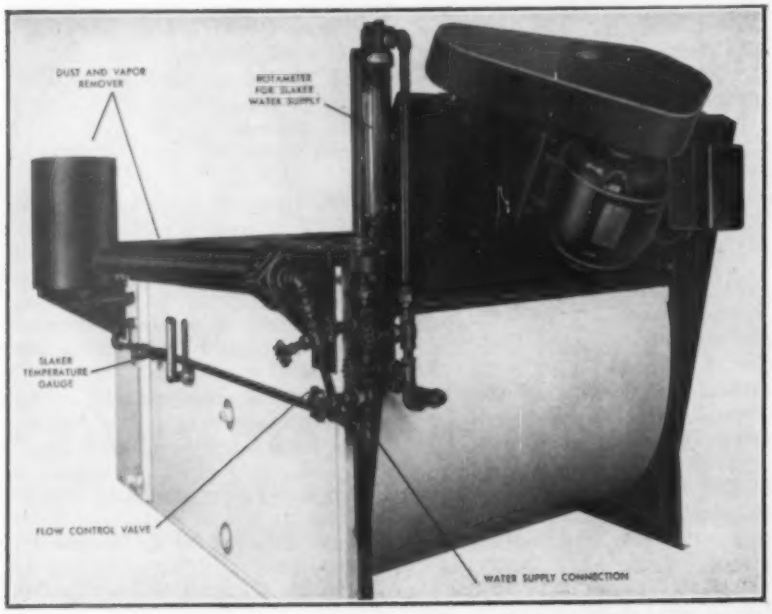
Assistant Director of the Department of Public Utilities in Richmond, Va.

LIME IS one of the oldest chemicals known to civilization, yet today the efficient utilization of this important chemical is impeded by lack of complete information concerning its physical and chemical properties. Since lime is used in such large quantities for softening and corrosion control in the water works field, it is amazing that so little information is to be found in water works literature on the subject of lime and lime slaking.

There is Lime and Lime

Limestone, which is the source of the calcium oxide, varies in physical and chemical properties in different parts of the country. Some limestone is high in magnesium, which is objectionable for use in water purification plants yet suitable for other chemical processes. Other sources are high in iron and silica content, so it is well to study analysis of the raw stone before buying lime for the water plant. At the lime plant, in the first step of processing the rock for calcining, a superior finished product results if mud, sand, and other impurities are removed before burning. In the actual calcining step, the manufacturer can control both the physical and chemical properties of the lime, either by the type of kiln or the method of firing. Therefore, much lime is either underburned or overburned by lack of control of the process at the kiln.

For example, the lime burned in the old style vertical kiln using coal as a source of heat without modern control equipment slakes very slowly. On the other hand, the modern controlled rotary kiln produces lime that will slake so rapidly that it actually explodes in the slaker. The author recalls an amusing incident at the Richmond water filtration plant on changing from a vertical kiln to a rotary kiln lime. The operator frantically called to report that the lime slaker was out of order and making a terrible rumble in the slaking chamber. On investigation, the new rotary kiln lime was producing miniature explosions that sounded like a loose agitator blade. Also common to the old style vertical kiln is the large percentage of core as compared to practically core-free lime from the rotary kiln. Thus it can be seen that all lime is not the same from every lime plant and the water works executive must choose the source of lime carefully if highest efficiency is to result.



Courtesy Omega Mach. Co.

Fig. 1.—TYPE of lime slaker used in Richmond, Va.
Illustration shows rotameter, flow control, dust remover, and temperature gage

Lime Properties

After the lime leaves the kiln it must be graded as to size. Quick lime can be furnished in sizes varying from a fine pulverized product, which will pass a 200-mesh screen, to a pebble lime of 2-inch size. In determining the proper size to use in the plant, the operator must remember that the pulverized lime offers both a dust problem and a feeding problem due to arching in the hopper. Dust can be controlled by proper ventilating system, but arching is just a universal worry. Arching can be partly corrected by design of lightweight hoppers having a bottom slope of not less than 60° from the horizontal.

Vibrators on the side of the hopper will further reduce arching, but the best answer is the use of pebble lime from ¼-inch to ¾-inch in size, provided suitable feeding and slaking equipment is available. Dust is reduced, arching in hoppers is elimi-

nated, and air-slaking of lime in storage is not as rapid with pebble lime as with pulverized lime.

Another physical property of interest is the color of the lime; white, gray, black, blue, etc. All are high in calcium oxide, and color is not a criterion of a good lime. The chemical properties and specifications are easy to determine in the laboratory. The lime should contain not less than 85 per cent CaO, have a low magnesia, silica, and iron content, and be free of arsenic.

In many plants today, calcium hydroxide (hydrated lime) is preferred to calcium oxide, due largely to lack of information and equipment for slaking the oxide. The lime manufacturer is anxious to dispose of calcium hydroxide, since all fines from calcium oxide are converted into calcium hydroxide at the lime plant. The water works executive must remember that he pays for the slaking process plus freight on water in hauling hydrated lime in preference to burned lime.

Economic Considerations

In Table 1, a typical analysis and price of calcium hydroxide as compared to calcium oxide shows the economic status of the two types of lime. In buying a typical pebble calcium oxide in place of calcium hydroxide, a net saving of $7.00 per ton of CaO equivalents is realized, plus higher operating efficiency. In actual plant operation the saving will be greater, since the theoretical ratio of one part CaO to 1.32 parts $Ca(OH)_2$ approaches a practical operating ratio of 1 part CaO to 1.5 parts $Ca(OH)_2$.

Another way to save money in buying quick lime is in the size of the lime. A pulverized calcium oxide (passing a 200-mesh sieve) is more costly than a standard pebble or cracked lime. The manufacturer must charge for the expensive process of pulverizing and will raise the price of calcium oxide for the pulverized product. Also for large plants, lime shipped in 15-ton cars costs more than in 25-ton car, due to the freight rates.

With the money that can be saved by shifting from calcium hydroxide to pebble calcium oxide, an execellent feeder and slaker can be purchased and the lime treatment will become a controlled process rather than the usual "hit-or-miss" process. The operator should investigate and experiment with different types of lime to find the one best suited to his own plant and local conditions.

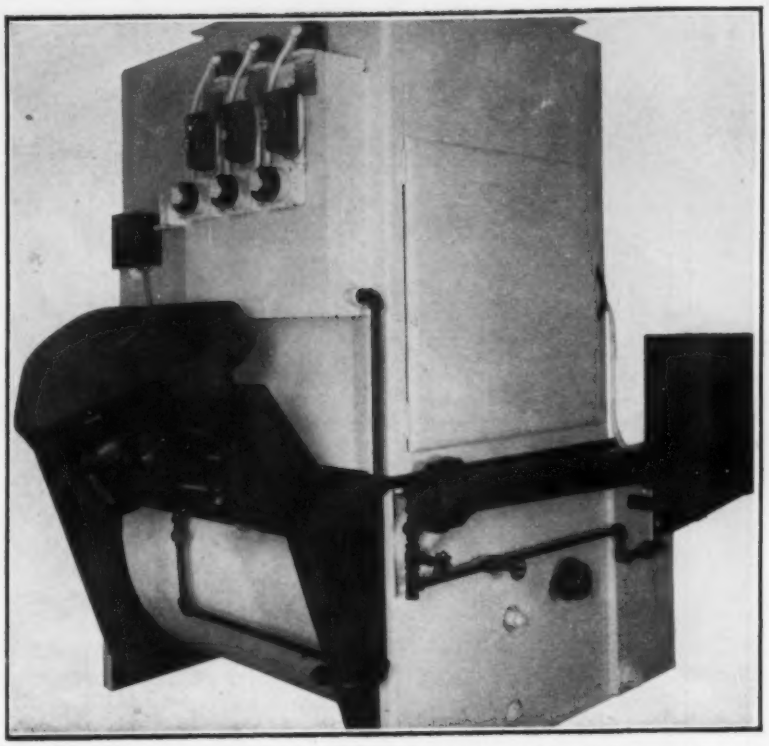


Fig. 2—REAR VIEW loss-in-weight feeder and lime slaker, 250 lb per hour. Note special electric heaters for Richmond, Va.

Lime Slaking Equipment and Operation

The operation of the slaker is not easy. Like a man learning to ride a bicycle, the problem looks simple yet requires initial research and a few hard knocks before the art is mastered.

First, and most essential, is an efficient dry-feeder. In the Richmond filtration plant, an Omega lime feeder delivers the lime to the slaking vat at an exceptionally accurate rate. The feeder is of the gravimetric batch type, having a maximum capacity of 250 pounds per hour and a minimum capacity of 2.5 pounds per hour. The feeder has a 1,000-pound capacity, and a properly designed hopper equipped with an agitator and mounted on a sensitive beam scale. The adjusting mechanism for changing the rate of feed is located in a compact unit with an alarm to indicate any trouble in feeding, such as an empty hopper or failure of material to leave the hopper. The lime feed is controlled by the vibrating plate at the bottom of the hopper.

The pebble lime, not exceeding ¾-inch size, falls off the vibrating plate directly into a compact Omega slaker located on the same floor with the feeder. The unit is equipped with a water-operated vapor removal system to collect dust and steam from the slaker. The water from this unit is not wasted, but is used as make-up water for the slaker or in conveying the lime to the point of application. The slaker has a minimum retention period of 30 minutes at the maximum rate of feed and is agitated with a motor-driven impeller so adjusted as to give proper circulation in the chamber. The type of slaker used is shown in Fig. 1.

TABLE I

Economical Comparison of CaO and $Ca(OH)_2$

ITEM	Typical Calcium Oxide Lime	Typical Calcium Hydroxide Lime
Insoluble Residue, %	1.3	1.2
R_2O_3, %	1.8	1.6
Loss on ignition, %	1.0	2.10
Magnesium oxide, %	1.9	.50
Calcium oxide, %	88.0	92.00*
CaO equivalents, %	94.0	70.00
Cost, bulk, del. per ton	$17.00	$17.50
Cost, CaO, del. per ton	$18.00	$25.00

Calcium hydroxide—$Ca(OH)_2$ or $CaO+H_2O$.

Temperature Control is Important

The optimum temperature for slaking will vary both with the type of lime and the retention period in the slaker. The most efficient slaker temperature range is between 160° and 180°F; above 180°F the steam and vapor will overload the vapor re-

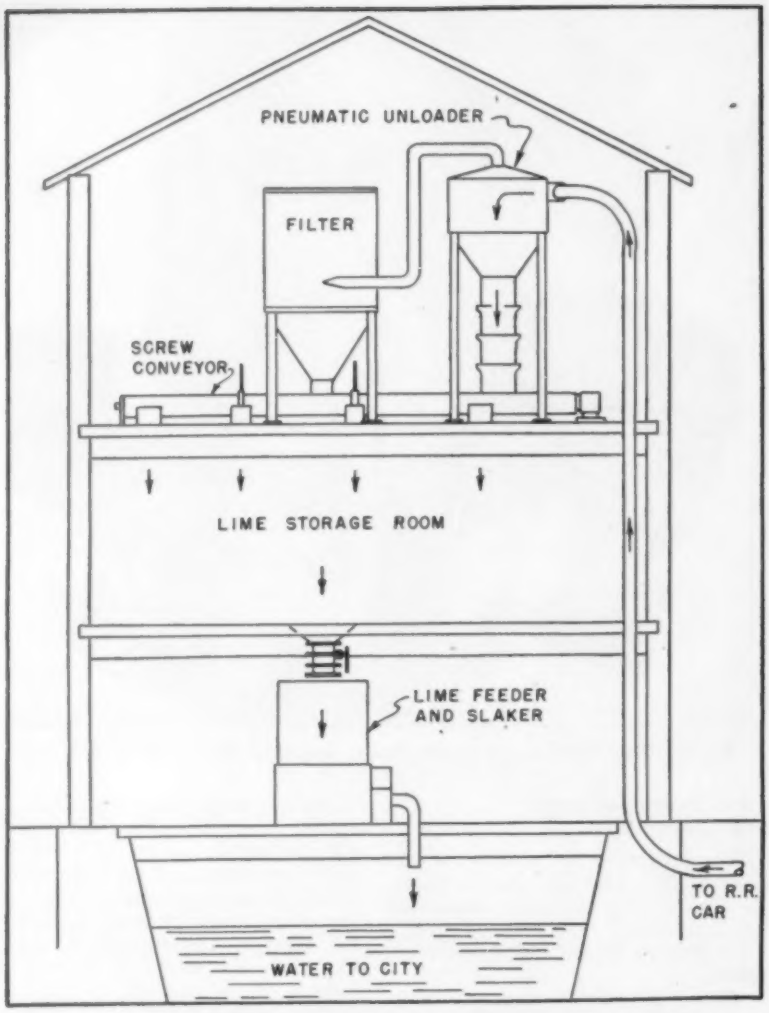


Fig. 3—LIME HOUSE arrangement at Richmond, Va., water plant

moval equipment and cause corrosion of the slaker and feeder. In the Richmond plant, the optimum temperature is 160°F using a pebble lime having a 96 per cent CaO content. To maintain this temperature in the shaker, with the incoming water varying between 33° and 85°F, an electric water heater of three No. M-240, 4-000-watt Chromolox immersion heaters was purchased for the job. (See Fig. 2). The heaters are equipped with three-way switches for seasonal control and thermostats on each unit to supply make-up water at a uniform temperature regardless of the temperature of the incoming water. The heat of hydration of calcium oxide is 273 calories per gram. However, in slaking small quantities of lime some of this heat is lost and must be supplemented by heat from the make-up water.

Proper Water to Lime Ratio

In slaking lime, too little water gives a heavy slurry that is too thick to be agitated properly by the impeller, yet an excess of water increases the expense of heating make-up water and dilutes the lime so that maximum retention time in the slaker is materially reduced. Different brands of lime require variable quantities of water, but a slurry of the proper viscosity is usually obtained by a range in ratio of lime to water from 1:3 to a ratio of 1:5. After a series of experiments at the Richmond plant the ratio of 1:4 was adopted. This ratio gives excellent operating results.

To control the ratio, a standard water meter is connected in the supply line to the heater. The meter is geared so that the lowest dial actually reads three times the amount of water passing through the meter. For example, 1 cubic foot of water passing through the meter indicates 3 cubic feet on the dial. This method was devised to afford the operator a chance to check the water flow at low rates much more readily than with the regular meter dial. After checking the flow, the operator refers to a chart (see Table 2) showing the meter reading corresponding to each rate of lime feed for a ratio of 1:4, adjustment being made by the needle control valve if necessary. Example: Feed of 50 pounds of lime per hour requires (for ratio 1:4) 50 x 4 or 200 pounds of water, or 3.2 cubic feet per hour. On the special dial this reads 3.2 x 3 or 9.6. On the chart opposite the rate of 50 pounds per hour is the value 9.6, which should be the reading of the meter for one hour. The operator adjusts the valve to get this reading. Another method of measuring the water is through use of a rotameter, as in the equipment in Fig. 1.

The lime after slaking is diluted with water from the vapor removal unit and flows over a weir into the outlet line. Some lime has considerable core. Therefore, the machine is designed for core removal, without stopping the slaker operation. The core is removed to a chamber to be washed to recover any calcium hydroxide on the surface and then is dumped into a trash can under the slaker.

TABLE 2

Water Meter Reading vs Dial Setting for Optimum Ratio 1 Lime to 4 Water

Lime Feed, lb./hr	Dial Setting	Meter Reading,* cu ft
1.75	1	.3
8.75	5	1.6
17.50	10	3.4
26.25	15	5.0
35.00	20	6.7
43.75	25	8.4
52.50	30	10.0
61.25	35	11.7
70.00	40	13.5
78.75	45	15.1
87.50	50	16.7
96.25	55	18.4

*Special meter dial; indicates three times actual flow.

Piping Lime Suspensions

No other problem seems more perplexing than that of transporting the lime to the point of application 300 feet or 400 feet from the slaker. Many plants use rubber hose and clean the line by beating or shaking the hose. The author has found that the open trough is the simplest method of delivering the lime, provided the necessary fall can be ob-

TABLE 3

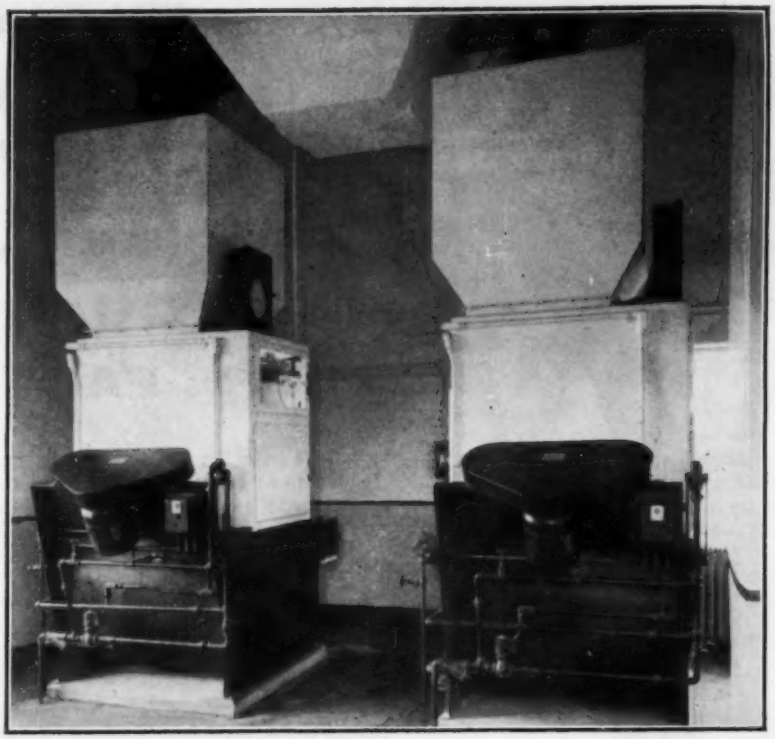
Station No. 34*
Location—Broad Rock Road

Determination	Before Slaker Installation 1938	1940	After Slaker Installation 1956
Res. Cl_2	0.00	0.00	0.05
Turb.	6.0	0.80	0.10
Color	40	10	3
Alk. (MO)	23	36	24
Alk. (phen.)	0	4.5	2.2
CO_2	0	0	0
pH	8.1	8.6	8.7
Fe_2O_3	4.0	0.40	0.00

*This station is located near a dead-end.

tained between the machine and the point of application.

In the design of a new plant the solution lines can be kept to a minimum by locating equipment close to the point of application. At the new purification plant in Richmond, the lime house is located over the effluent wells and the solution line is only 3 feet in length. Fig. 3 shows the arrangement of the lime house with the pneumatic unloader, storage bins and feed machines. This system provides minimum handling of lime and no difficulties have been experienced in maintenance or operation of the machines or solution lines.



TWIN installation of loss-in-weight feeders and lime slakers at Scituate, R. I.

pH Control Simplified

So accurate is the control of pH with the new Omega slaker that in the Richmond plant a constant pH of 8.7 can be held in the finished water. It is important to note in Table 3 that prior to the installation of the slaker, there was trouble in the distribution system with a decided drop in pH. With the present slaker there is only a slight drop and a corresponding decrease of iron in the dead-ends. This can only be explained by the fact that the controlled slaking is productive of a more highly peptized lime suspension—more nearly a colloidal suspension.

It is hoped that waterworks men will study lime treatment and get more lime per dollar. It must be remembered that obsolete equipment often can be scrapped and new equipment purchased with the saving, so why not have a modern plant at no extra cost?

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COAGULATION, MIXING AND SEDIMENTATION

CLARIFICATION is the term applied to the removal of suspended and dispersed matter from liquid by means other than filtration. Coagulation is a two phase process of mixing and flocculation to produce destabilization and agglomeration of colliods and finely divided suspended matter by the addition of a floc-forming chemical coagulant.

Mixing, the first phase of coagulation, consists of violent agitation of the liquid and coagulant for the purpose of rapidly dispersing the dissolved coagulant. Flocculation, the second phase of coagulation, is the term applied to the show agitation of a liquid containing a coagulant to cause the growth of floc particles by collision, aggregation and coalescence of colloids and suspended solids. Sedimentation or settling is the process or subsidence and deposition under the influence of gravity of suspended matter in water or sewage.

Mechanism

The mechanism of coagulation involves the destabiligation of electricity charged colloids by using certain chemicals such as aluminum or iron compounds, the ions of which carry electric charges. Hydrous oxides of flocculant nature form to aid in the entrappment and settling of fine particles.

The need for coagulation in water treatment is especially important to the removal of objectionable suspended and colloidal matter. Coagulation, followed by sedimentation reduces the load on sand filters, improves filter operation and increases filter runs. Coagulation, also may be helpful to reduce color, and iron and maganese.

In sewage treatment, chemicals coagulation, when used is for the same purpose as in water treatment, namely to agglomerate and remove colloidal suspended matter.

Coagulation Factors

Certain factors in coagulation are subject to control. These are choice of coagulant, quantity of coagulant, mixing and flocculation time. Other factors which affect coagulation are not subject to control; these are amount and character fo impurity, chemical characteristics of the water and temperature of the water. Coagulation aids include the addition of artificial nuclei, solids-contact in up flow clarifiers, and activated silica. In coagulation practice, control is important. One means of control is the "Jar Test Procedure".

Other factors in coagulation are points of application, need for added alkalinity, possible effect of prechlorination, use of activated silica or activated carbon, and sequence of addition of chemicals.

Mixing

Mixing of the coagulant chemical with water or sewage may be accomplished by mixing basins or mechanical mixers. Mixing basins are usually baffled with baffles being either vertical or horizontal.

Mechanical mixing devices can provide an optimum rate of mixing both for rapid dispersion of coagulant and for slow flocculation reaction, independently of rate of flow. Rapid or flash mixers usually are high speed paddles. Flash mixing is generally kept to below 15 seconds and not more than 60 seconds even in large mixing basins or wells.

Flocculation may be used without chemicals in sewage treatment to increase the size of the particles and thereby improve settling and removal of suspended matter. Flocculating basins contain slow moving paddles or lattice baffles which revolve at peripheral speeds below 1.3 ft per sec. One type of flocculator consists of paddles tranverse to flow. They rotate out of phase and impart a barrel roll effect in the water. Another type has paddles on a shaft longitudinally parallel to direction of flow. A third type is the "walking beam" flocculator. Other mixing devices include the hydraulic jump and mild aeration.

Sedimentation

Particles, in water or sewage, having a density greater than that of water will settle under quiescent conditions. The object of sedimentation basins is to reduce the velocity of flow toward quiescent conditions so that the carrying power of flowing liquid will be reduced and settling of suspended particles will occur.

Many factors affect actual sedimentation; these are specific gravity of solids, movement of water, shape and concentration of particles. In practice, the object is to provide not only a slowing of the water but also space for storage of the settled solids and means for removing these solids.

In the ideal basin, the detention time is the length of time for a segment of flow from one end of the tank to another. Detention time is calculated by dividing the volume of the tank by the rate of flow through it and in essence is a function of the overflow rate.

Flow-through time as opposed to theoretical detention time is the minimum time required for a particle of water to pass through a settling tank. The detention period is from two to twenty times the flow-through period. Among the factors which affect the flow-through time are stray currents, short circuiting, and design of inlet and outlet structures.

Sedimentation Tanks

Factors which are important in the design of sedimentation basins are: plant capacity type of treatment, number of basins, size and shape of basins, inlet and outlet arrangements, overflow rate, velocity of linear flow, sludge storage and removal. Settling tanks may be rectangular, circular, upflow, two-story, and concentric.

Removal of sludge solids as rapidly as they accumulate, is desirable in both water and sewage plants in order to prevent putrefaction of organic matter. Mechanical removal of sludge is practiced in nearly all circular and many rectangular tank installations. In circular tanks, scrapers or plows attached to rotating arms, plow the settled sludge to a center sump from which it is pumped. In rectangular tanks, scrapers or flights scrape along the bottom and move the sludge to an end sump, from which it is removed.

Use of mechanical sludge collecting devices appear to be economical when the volume of sludge is more than 0.1 per cent of the volume of liquid flowing. In water plants, and especially in water softening a portion of the sludge can be returned to incoming water to act as a coagulant aid by providing nuclei. In sewage sedimentation, a portion of the settled sludge can be returned to incoming sewage for the same purpose of aiding flocculation but aerobic conditions must be maintained. Upflow clairfiers may be effectively used for the purpose of providing nuclei and improved flocculation.

Activated Silica Preparation by Continuous Processes

by V. W. LANGWORTHY

Chief Applications Engineer, Omega Machine Co., B-I-F Industries, Inc., Providence, R. I.

NOW, ACTIVATED SILICA can be produced successfully on a continuous basis. Today, the time-and-space-consuming batch methods are outmoded although it must be acknowledged that continuous activation of silica by various reagents has evolved naturally from the old batch processes. Activated silica as a coagulant aid has been shown to be remarkable in its ability to assist in the clarification of warm or cold, turbid or colored surface waters. Properly prepared and applied it can reduce the load on sand filters by forming a floc which will ride out hydraulic surges in conventional or sludge blanket type clarifiers.

While the use of activated silica sol and the benefits to be derived from its use as a coagulant aid are fairly well appreciated, it is desirable to know more about additional factors involved. This paper discusses equipment requirements, operating techniques, characteristics of the common activating agents and elements entering into control of the activating process.

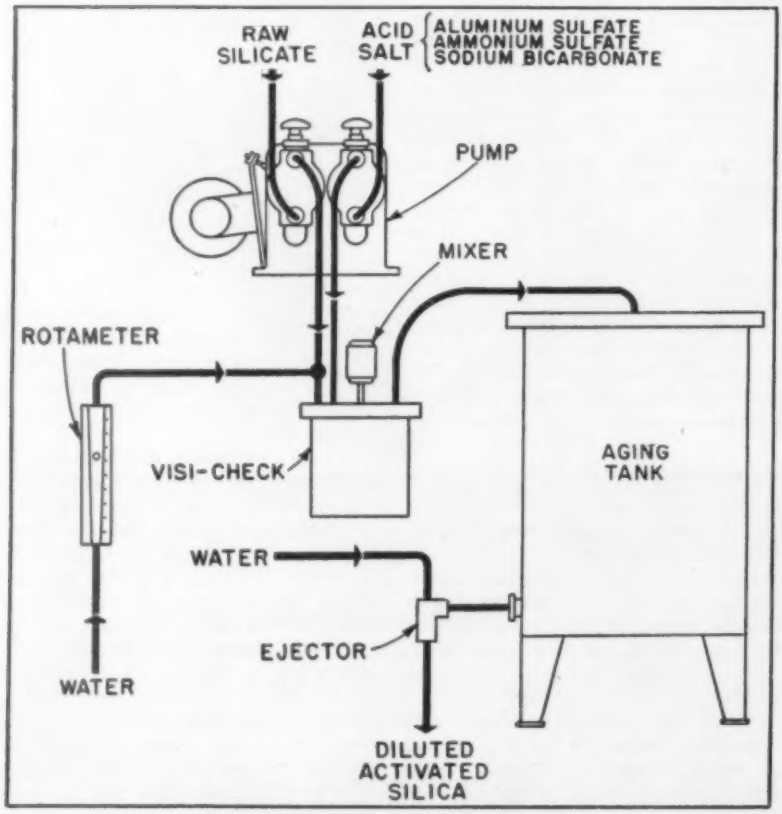

Fig. 1. FLOW diagram of continuous silica activation by acid salt.

Equipment Requirements

It is necessary that accurate control be maintained over the raw sodium silicate and activating agent to be used in the process. For this purpose equipment of choice is a positive displacement type pump, which must have reproducible accuracy and be capable of adjustment while in operation. Capacity and range of the pump must be compatable with other items of equipment employed.

At least one water meter should be provided to establish a known concentration of raw sodium silicate and activating agent. Variable orifice meters of the rotameter type have proved satisfactory for this purpose.

The importance of *intimate* and *complete* mixing between raw sodium silicate, activating agent and dilution water cannot be over-emphasized. The success or failure of the activated silica process largely depends on efficient mixing of controlled quantities of reagents at the proper concentrations. Hydraulic, mechanical or air mixing may be selected. Air mixing, however, may introduce troublesome reactions and likely will entail the expense of auxiliary air compressing and control equipment.

Aging

In order that a properly prepared activated silica sol may reach its maximum activity, a period of aging must be provided. Experience in the laboratory and on plant scale has indicated that aging requirements vary with the relative strengths of activating agent used in relation to a given volume of raw sodium silicate. In general, the higher ratios of activating agent per unit volume of raw sodium silicate require less aging. It has also been observed in rare instances, that formal aging of the silica sol may not be required to im-

prove coagulation in some raw waters. To produce a sufficiently active sol for most water treatment problems it is practicable to employ an aging period of approximately ten minutes by adjusting the strength of the activating agent to the point of greatest observed effect on flocculation.

Equipment for continuous silica activation should be supplied with aging capacity. This capacity should be sufficient to retain the sol at aging concentration for ten minutes when the rated *maximum* amount of activated silica is being produced. For example, if the total volume of raw silicate solution and solution of activating agent is 10 gallons per minute, at least a 100 gallon aging capacity vessel or chamber would be required to detain the sol for a ten-minute aging period.

Adjustable features should be provided in the aging unit so that ten-minute aging can be assured at all rates of activated silica production. Inasmuch as the process is continuous, aging equipment should be designed to minimize short circuiting and permit aging time adjustment without interruption to the process.

Transferral

The final item of equipment in continuous silica activation is that employed to conduct the active sol to the point of application. Gravity is the preferred means of delivery, but pumps of many types can and are being used for this purpose at numerous installations. The importance of *liberal* dilution of the activated silica sol for delivery to the point of application must be recognized. The tendency for objectional silica gel to form is virtually eliminated when the 10 minute aged sol is diluted. Therefore, the volume of sol being prepared should be diluted with an equal amount of water either for transfer or for holding purposes.

Avoiding Operating Errors

It is possible to provide certain features in continuous silica activating equipment which overcome some of the common operating errors. If water used by the equipment is required to pass through a flow switch, controlling all electrical circuitry, it becomes impossible to operate the equipment with insufficient water. This is an advantage in that it prevents starting the raw sodium silicate and activating agent flows without first turning on the diluting water supply to the unit.

Interference with the process can also be caused by failure of the raw sodium silicate pumps to deliver. Means should therefore be provided to detect this failure and to do something about it. If insufficient raw sodium silicate were delivered to the system, an excess of activating agent would result. This situation can lead to silica gel formation rapidly if allowed to continue. To avoid gelation, under this condition, it is therefore desirable either to shut off the supply of activating agent, or to provide copious amounts of rinse water automatically. An automatic rinse feature will permit resumption of normal operation merely by correcting the interference.

Automatic rinsing also eliminates the problem of human forgetfulness at shutdown time. In the event the operator shuts down the equipment, gelation is prevented by dilution effected through the automatic rinse system. This is greatly to be desired over cleaning out the system once gel has formed. Such an automatic rinse feature can be timed for a predetermined period, or the entire system can be turned off manually after rinsing. Under all circumstances, an automatic rinse arrangement should be incorporated in any continuous silica activating installation.

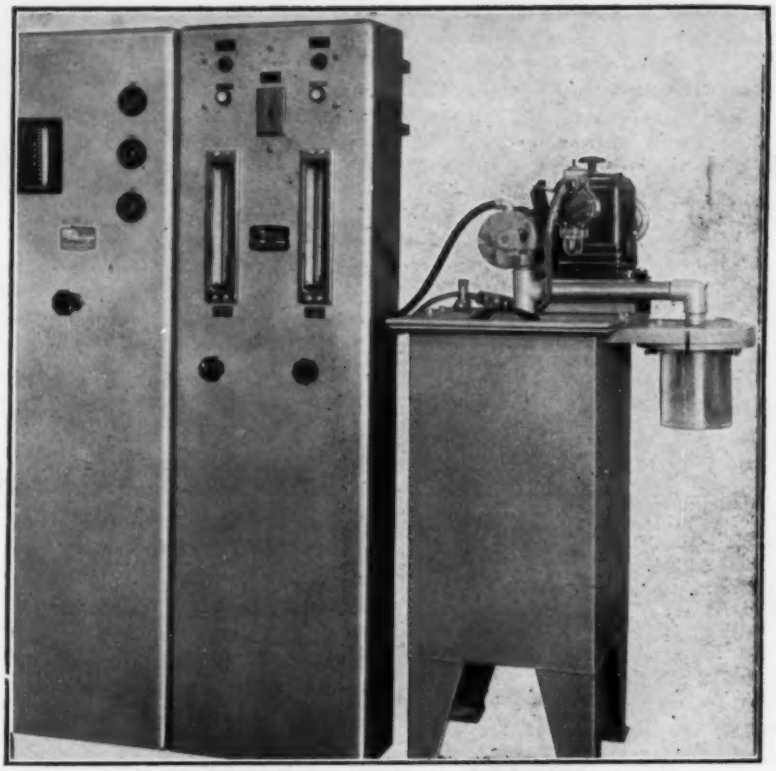

Fig. 2. CHLORINE type continuous silica activating equipment.

Constant strength chlorine device at left, control panel in center and mixing-aging system at right. Pump handles sodium silicate.

Selection of Activating Agent

Several acidic reagents have been used successfully for continuously activating silica. Among these are chlorine, sulfuric acid, ammonium sulfate, aluminum sulfate, sodium bicarbonate and carbon dioxide. A typical composite flow diagram for acid salts is shown in Figure 1. Ferric sulfate also has been used as an activant in at least one West coast installation.

Selection of chlorine as the activating agent is popular, because chlorine used in the activation process is also available for disinfection or other purposes. Chlorine is simple to use and is readily available in most water treatment plants. Unfortunately, the ordinary chlorine gas feeding equipment does not lend itself readily for use with silica activating devices. The reason is that the regular chlorinator injector dilutes the chlorine solution too much.

Although chlorine is a desirable activating agent, it does have shortcomings. For example, where low rates of raw water having low chlorine demand require treatment with activated silica, too much chlorine often is added by the chlorine type equipment. This is an anomaly,

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- Clean, easy to handle
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- Clear, colorless effluents are possible
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- Treated digested sludge dries quickly with a minimum of odor
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wherein any reduction in chlorine used produces an inferior activated silica. Therefore, while chlorine is readily available, it will not in every case be the best reagent to use in the silica activating process. A typical chlorine activated silica unit is shown in Fig. 2.

Sulfuric acid is considered the least expensive activating reagent. Many operators, however, prefer not to handle the acid unless absolutely necessary. With adequate precautions, sulfuric acid may be used successfully at both large and small plants as a silica activant. Figure 3 illustrates a sulfuric acid type silica activator.

Ammonium sulfate is often used in connection with the chlorine-ammonia process at water treatment plants. It is also readily available in tonnage lots at reasonable prices. The technical grade product is crystalline, free flowing and possesses a high solubility in water. It is a good activating agent where small amounts of ammonia will not interfere in the treatment process, or with subsequent water uses.

Aluminum sulfate has enjoyed widespread use as a coagulant in water treatment plants in this country. It is readily available and easy to handle, These characteristics plus its good solubility render it highly desirable as an activating agent. It should be noted, too, that a portion of the alum used in the activation process remains available as aluminum hydroxide for use as a coagulant.

Sodium bicarbonate is an inexpensive reagent highly satisfactory for use as an activant. It has a comparatively low solubility in water which makes it less suitable than the acid salts already mentioned. The weak acid tendency, however, provides a process which is easy to control because of the high buffering action of the bicarbonate. Also, the tendency to gel is less dominant in the bicarbonate process than in the alum or ammonium sulfate methods.

Carbon dioxide has been used successfully in batch-wise preparation of activated silica. Its adaptation to continuous processes has been limited primarily due to its low solubility in water. The gas is not readily available at economical prices in tonnage lots, nor is the solid product (dry ice) easily adaptable for use. At least one Florida installation uses flue gas as a source of carbon dioxide, but this practice has not become widespread.

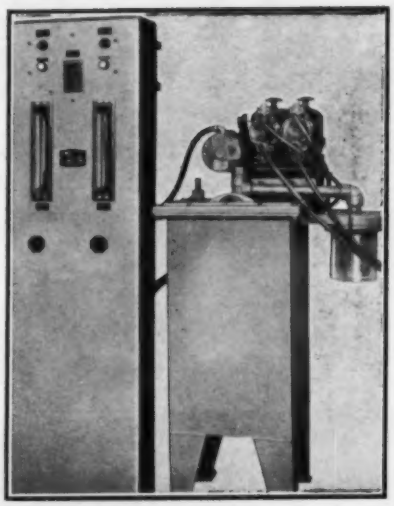


Fig. 3. SULPHURIC acid type continuous silica activating equipment.

Activating agent selection should be made, in part, on the basis of the reagent which produces the best coagulant aid, helpful in solving the local coagulation problem. Many plant operators use jar tests as a means of selecting appropriate coagulant dosage. The same test will indicate the silica activating agent best suited to local raw water conditions.

Interchangeability of activating agents is simplified when dry reagents are used. The problem is simply one of selecting the chemical, dissolving it and delivering the proper volume of constant strength solution to the mixing and aging equipment. Equipment used in feeding gaseous reagents does not possess this flexibility.

Process Control

Silica activation may be considered a neutralization reaction. The end product sought is a controlled suspension of colloidal silica. It should be possible to control the activation process by titration, gel time, pH, conductivity, viscosity, or light transmittancy. It has been found that titration is a reliable means of control. Total alkalinity of the aged sol will depend on the activating agent used.

Where chlorine is the activating agent, the titration for available chlorine may be used as a guide. In the acid salt reactions straight titrations for total alkalinity may be used. The objective is to obtain the best sol short of gel formation. This means that the titration end point selected should give a gel time longer than the aging period required by the activating equipment.

Gel time can be used as a means of determining the aging period, no other tests being required. The gel time for certain type sols may be extremely long, rendering the results obsolete by the time they are obtained. Short gel time, such as that obtained where chlorine or sulfuric acid is used, is more appropriate for use as a guide. Gel time remains valuable usually as a check against the easily performed and reliable titration.

The remaining control procedures, pH, conductivity, viscosity, and transmittancy all have application where precise study and exhaustive data are desired. However, the normal operation of activated silica equipment does not require or justify expenditure for the necessary instruments required for these tests.

In Summary

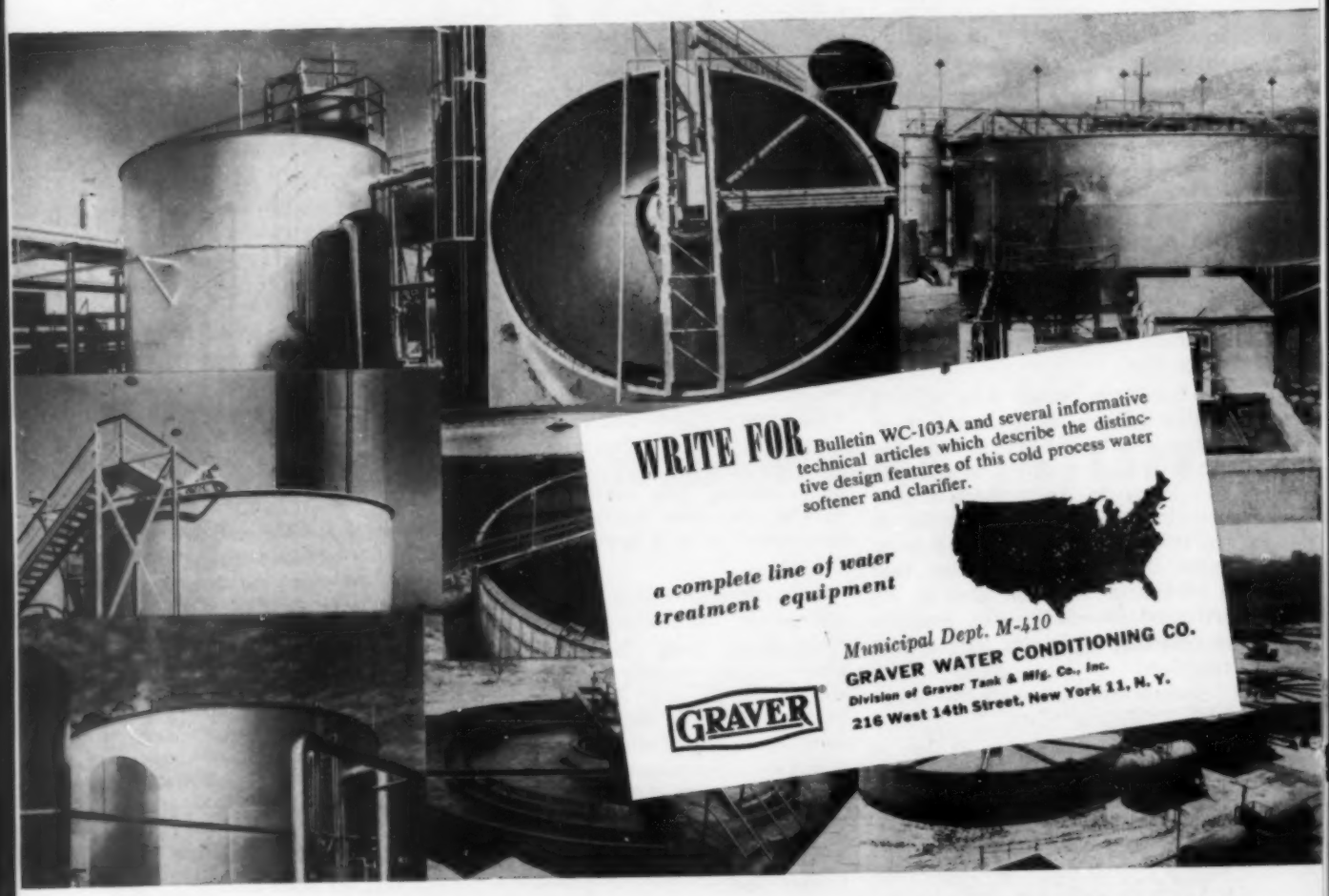
Continuous silica activation requires dependable equipment accurately calibrated if satisfactory results are to be obtained. The process should include efficient mixing and provision for control over the aging period. It is desirable to include automatic interlocks to guard against improper start-up and to provide rinsing at shutdown. While these features are not mandatory, they contribute an intangible peace of mind to the operator and are insurance against non-performance.

Ideally, the silica activating equipment should provide for interchangeability of activating agents. This feature allows the operator freedom of choice of activant both before and after equipment purchase. Activant selection should be based primarily on the results produced; secondary considerations, however, are availability, safety, economy and chemical characteristics.

The activation process may be controlled in several ways. Titration and gel time have proved to be the most practical means available.

NATIONWIDE

HIGH-RATE WATER TREATMENT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Bentonite Clay As A Coagulant Aid

Increased Filter Runs a Noteworthy Gain

by LEO LOUIS

Vice-President and General Manager of the Gary-Hobart Water Corp., Gary, Ind.

THE FILTRATION PLANT of the Gary-Hobart Water Corporation in Gary, Indiana, is one of the newest in the state, having been placed in operation in May 1954. Gary's raw water supply, from Lake Michigan, is relatively good when compared with other Lake Michigan supplies. In fact, the first 46 years of its history the Gary water supply was chlorinated lake water, without benefit of coagulation, settling, or filtration.

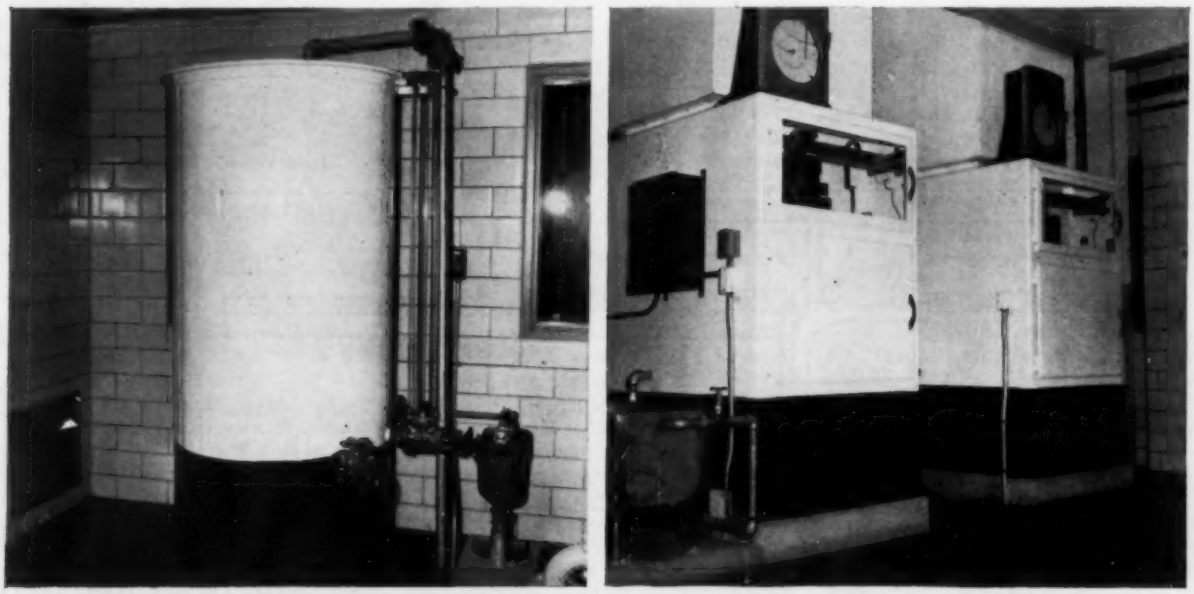
Customer complaints of turbid water after storms over the lake increased through the years with Gary's growth, and plans for a filtration plant were developed by Alvord, Burdick and Howson, consulting engineers, Chicago, in the late 1940's for the then owners, Northern Indiana Public Service Company. These plans were delayed by the decision of that owner to sell all water property, which sale was consummated in May 1951. The newly organized company, Gary-Hobart Water Corporation, asked the same consulting firm to proceed with the design of the plant and in 1952 began the construction of the new treatment facilities. Incidentally, the engineering firm of Alvord and Burdick had laid out the original water system for the first Gary water supply in 1906-08.

The new filtration plant was placed in operation on May 1, 1954, the third anniversary of the new company. Design of the plant is conventional for Lake Michigan water. However, there are several notable exceptions to the strictly conventional design. These are:

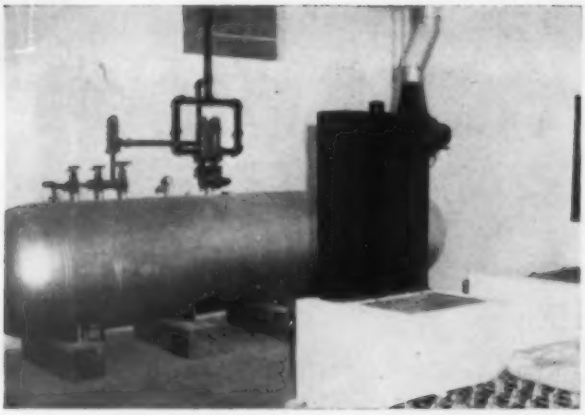
1—The six rapid sand filters were designed for a 36-mgd total capacity at a rate of 2 gallons per square foot per minute, but can be operated at a 3-gallon or 4-gallon rate to increase the capacity to 54 mgd or 72 mgd. Peak hour filter rates during the 1955 summer months were often above 54 mgd and approached 60 mgd.

2—The settling basins are two stories in height, with the water passing through the lower basin, thence upward and reverse through the upper basin (see drawing).

3— The mixing basins are at the same



CHEMICAL FEEDERS: One-day liquid alum tank and solution feed control (left); Omega dry feeders (right). The near unit is used as a Bentonite clay feeder—note improvised clay suspension box



AMMONIA STORAGE tank and charging floor for dry feeders (left); filter operating floor (right)

level with the upper settling basins and are equipped with mechanical revolving paddle flocculators. One of these mixing basins is located immediately below the general business office of the company.

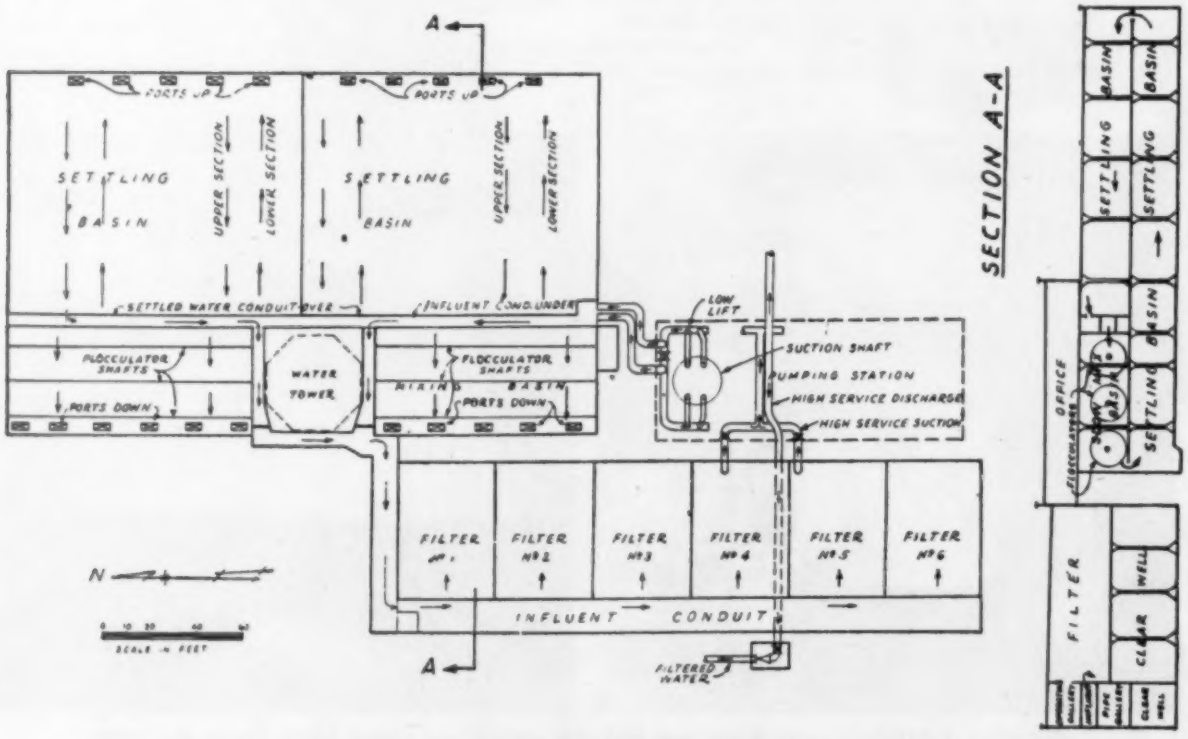
4—Because of the absence of a railroad siding at the plant site, liquid chemicals are utilized as much as possible to eliminate handling of dry chemicals. In addition to ton containers of liquid chlorine, liquid ammonia is delivered by truck and stored in a large steel storage tank, and liquid alum is generally used as a coagulant. This plant was probably the first municipal water plant to utilize liquid alum delivered by tank truck directly from the supplier's plant to the filtration plant.

The Algae—
Short Filter Run Problem

As a part of coagulation, a problem arises in Gary during the summer months when algae counts are high in the clear raw lake water and the algae become difficult to settle before filtration. The dead algae cells tend to clog the filters and reduce filter runs tremendously. This condition becomes most serious at a water temperature of approximately 60° F in the early summer and again in the fall.

In 1954, during the first summer's operation of the filtration plant, filter runs dropped to 4 hours or less and ordinary coagulation aids such as lime did not seem to help the situation. The turbidity of the raw water was extremely low and good floc formation was difficult. Algae identification pointed to asterionella, fragillaria and tabellaria as the cause of the shortened filter runs and high wash water consumption.

The plant chemist made inquiries of other filtration plants using Lake Michigan water and found that this condition was the same and equally



FLOW DIAGRAM and plan of the Gary filter plant. Note the double-deck settling basins

PUMPS AND LABORATORY: Three raw water pumps in well beyond two high service pumps

serious at most of the plants along the lake. He found that Wilmette, Illinois, had been experimenting both on a laboratory and a plant basis with Bentonite clay and had considerable success with it in weighting the algae-laden floc and assisting in settling. We arranged to borrow 4 tons of the material from Wilmette and experimented with it ourselves. On the basis of those experiments we and the Michigan City Water Department jointly bought a carload of the bagged clay.

The results were good enough in 1954 to warrant the purchase of another carload in 1955. The Bentonite clay is shipped in 100-pound multiwall paper bags and stored with the other bagged chemicals. It is fed through an Omega loss-in-weight gravimetric dry feeder ordinarily used for lime. The measured clay is mixed with water in a stainless steel solution box and pumped as a suspension to the raw water suction well. There has been little trouble in feeding the material.

According to information furnished by the manufacturer's agent, this material is produced by the American Colloid Company in two grades. One is Panther Creek Bentonite, which has its source in Aberdeen, Mississippi. The other is Volclay KWK, which comes from Belle Fourche, South Dakota. Panther Creek Bentonite is a light gray-tan powder, which when placed in water swells to three times its dry volume, where Volclay KWK is a cream-colored pelletized material which swells to ten times its dry volume.

The American Colloid Company, in their data sheet No. 200-A, explain further that Bentonite as produced by their plants includes only swelling montmorillonite type clay. The greater swelling Bentonites are used primarily in foundry molding processes and for use as drilling mud in the oil fields. It is also used as a detergent in commercial laundries.

The use of Bentonite as a coagulant aid in water treatment embraces its value not only as an artifcial turbidity producing material, but also as an adsorptive material with negative charges which attract the floc particles in the water and by absorption form larger heavier particles which will settle effectively.

The manufacturer's representative comments that while Volclay should give better efficiency in increasing turbidity and in picking up and holding bodies which may be causing short filter runs, the high swelling ability also causes it to be somewhat difficult to handle. Sheboygan, Wisconsin, and Wilmette and Winnetka, Illinois have all tried both type of clay; of the three cities, only Winnetka prefers Volclay. We have never tried Volclay or experimented with it and our expreiences have been solely with Panther Creek Bentonite.

Some of Our Experiences

Our experiences with Bentonite, both in 1954 and in 1955, demonstrated that the use of the material resulted in lengthened filter runs, although it is possible that other factors could have contributed to the change in filter performance.

In the latter part of June 1954, the length of filter runs dropped off from a minimum of 18 hours on June 14 to 4 hours from June 16 through June 19. On June 18 we had 19 filter washes. Some of these were only of 1-minute duration instead of the usual 4 minutes, but in addition we had to "bump" the filters frequently between washes. The condition was better on June 20, but became worse again on the following day with filter runs as low as 2 hours being recorded on June 25. On that day 21 filter washes were made, with additional filter "bumps".

Our average use of wash water is less than 2.5 per cent of the total water pumped through the plant, but during this period it averaged between 4 and 5 per cent. Pumpage and filter rates were higher than normal during this period and on June 25 the maximum hourly total filter rate was 56 mgd. Raw water turbidities were less than 10 ppm and algae counts were apparently high, although unforunately we do not have any record of these data. The total pumpage on June 25 reached a new record day of more than 38 million gallons, filter rates were over 3 gallons per square foot per minute, and with the 2-hour runs we were definitely in trouble. Continued "bumping" of the filters and short washes didn't help too much. Consequently, that day we sent a truck to Wilmette and borrowed 8,000 pounds of Bentonite.

On June 26 we started feeding the clay at a rate of 32 pounds per million gallons and on that day our filter runs lengthened to between 10 and 12 hours. On the 27th they increased again with the same feed rate and on June 28 we increased the feed rate to 40 pounds per million gallons. We have since used the 40-pound rate as the optimum feed. From June 27 until July 6 the filter runs gradually increased to an average of 50 to 60 hours. On June 29, however, we had 16 filter washes for some reason,

possibly because of a very high total filter rate on that day. Feeding of the clay had to be discontinued on July 7 because we had used up all of the material on hand. We had ordered a carload meanwhile, but this didn't arrive until July 13. On July 10 the runs had decreased to 31 hours and by July 13 we were down to 3 hours.

Late on that day we started feeding Bentonite again and by the next day we were back to runs of more than 10 hours. Bentonite was continued until July 26 and filter runs were maintained at normal levels with the exception of July 19 and 20, when again a high filter rate apparently caused more filter washes. This was during the peak pumping season and filter rates were quite often as high as 3 gallons per square foot per minute during this period.

In 1955, Bentonite was fed for a few days during the latter part of June and from July 6 to 25. The experience was about the same as in 1954. On June 21 the wash water use was 4 per cent of total pumpage with no clay; with two days of clay fed at a rate of 40 pounds per million gallons wash water use dropped to 1.3 per cent. On July 5, the wash water use was over 5 per cent and after clay feed was again started wash water use dropped to below 2 per cent.

It is difficult to state conclusively that the Bentonite was alone instrumental in increasing filter runs during these periods, as graphs indicate that filter rates fluctuated somewhat parallel to the filter wash water usage and filter runs. Nevertheless, the use of clay tended to keep water use at a lower level regardless of the filter rates. It is also true that our story isn't entirely complete due to the lack of data on algae counts. However, our plant personnel definitely feel that Bentonite clay contributed a great deal to better operation during these periods of high filter rates, when every drop of water that can be pumped into the system counts a great deal and having to shut down a filter for washing or having to rob the distribution system for filling the wash water tank presents many problems.

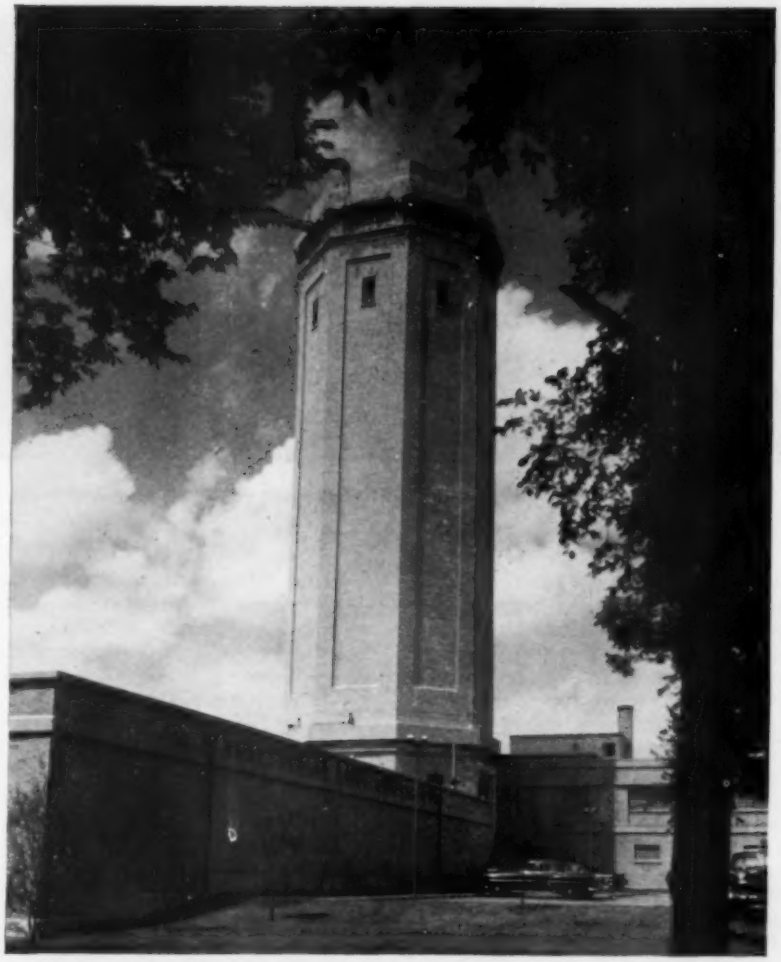
Aside from the more efficient operation resulting from the better coagulation, there could be a definite monetary savings if less wash water is used.

Costs and Savings

Panther Creek Bentonite costs us approximately $1.55 per 100 pounds FOB Gary in a 30-ton carload lot. Based on a feed rate of 40 pounds per million gallons, the additional cost of clay is approximately $0.62 per million gallons. The maximum pumpage day last year was 42 million gallons and if on that day we were able to reduce the number of washes from 21 to 8, as occurred when we first started feeding clay, we would save 13 washes at 130,000 gallons each, or a total of 1,690,000 gallons of water. Actually, some of the 21 washes were only of 1-minute duration rather than 4 minutes long, so the wash water savings would be closer to 1,000,000 gallons on that day. Our average purification and pumping cost at the main plant was approximately $30 per million gallons in 1955, so the savings on wash water for a day would be $30. The cost of Bentonite clay on the 42-mg day would be 42 x $0.62 = $26.04, or a little less than the cost of the extra water used in washing.

It is difficult to determine actual savings from plant records, as there are so many factors involved (such as day-to-day pumpage fluctuations, different filter rates during the night and day hours, and the habits of filter operators as to exactly when they might want to or be able to wash filters from one day to the next). The only way to obtain exact figures on this would be if parallel operation of two sections of a plant would be possible—one with Bentonite and one without. This would eliminate variables in the quality of the water during the test period.

In conclusion, the use of Bentonite clay as a coagulant aid in Lake Michigan water during periods of low turbidity in the presence of certain algae growths and while plant pumpages are high, appears to be conducive to extending filter runs with the consequent saving of wash water. Above the economy of wash water saved, however, is the advantage of not having to take filters out of operation so many times and not having to drop system pressure to fill the wash tank at frequent intervals.



FILTRATION PLANT built around original stand pipe, now brick encased for appearance sake and used as a wash water tank

Corrosion of Water Works Materials

by R. W. HENKE

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OF THE many problems confronting the water works engineer, corrosion occupies a position which is unique. It penetrates into all facets of his operation, is usually difficult to diagnose, and sometimes is impossible to eliminate. It is a phenomenon which we must learn to live with and control.

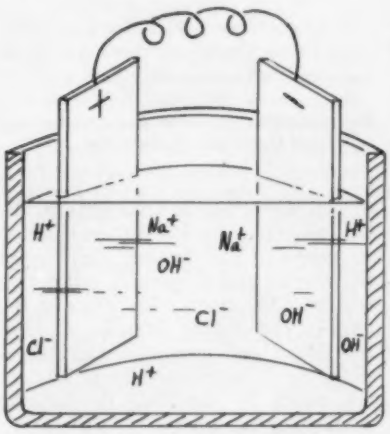

Fig. 1—GALVANIC BATTERY components

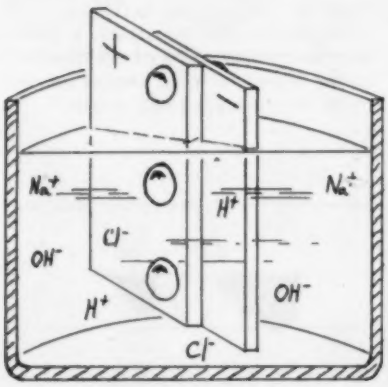

Fig. 2—GALVANIC CELL composed of two different metals bearing against each other

Corrosion as subject fills libraries and it is impractical to accomplish any more than present a few basic definitions and general discussion here.

What Corrosion is

As far as the water works field is concerned, corrosion may be defined as *the degradation of a material by the inadvertent action of chemical, mechanical or electrochemical means, or a combination thereof, so as to reduce the usefulness of the material.*

This definition attempts to encompass several points which the author feels are of fundamental importance, as follows:

1. The material attacked must be performing a useful function or be capable of performing one.
2. The usefulness of the material attacked must be reduced.
3. The attack must be inadvertant —unplanned, undesired, not wanted.

Kinds of Corrosion

There are many types of corrosive actions defined, not all of which are applicable to the water works field. Those covered in subsequent discussion will be the applicable corrosion phenomena.

Generally, water works equipment could be expected to be subjected to galvanic corrosion in its many forms, direct chemical attack, perhaps dezincification, erosion, impingement corrosion, possibly fretting corrosion.

Galvanic corrosion is the general term applied to electrolytic cell type corrosion. This has been popularly termed "electrolysis" in the water works field. It is an action best illustrated by the battery analogy, shown in Fig. 1.

Two different metals are connected by an electrical conductor and are submerged in an *electrolyte*, a conducting solution. An electric current is set up between the two metals. By popular notation, the current "leaves" the positive metal, the *anode*, and "enters" the negative metal, the *cathode*. The amount of current per unit area leaving either the anode or cathode is the *current density*. At the anode, the positive plate, the metal goes into solution. Therefore, the anode material is destroyed.

Keeping the battery of Fig. 1 in mind, refer to the set-up illustrated in Fig. 2. Here we have a galvanic cell set up between two different metals bearing against each other. The cell isn't as neatly defined as that of

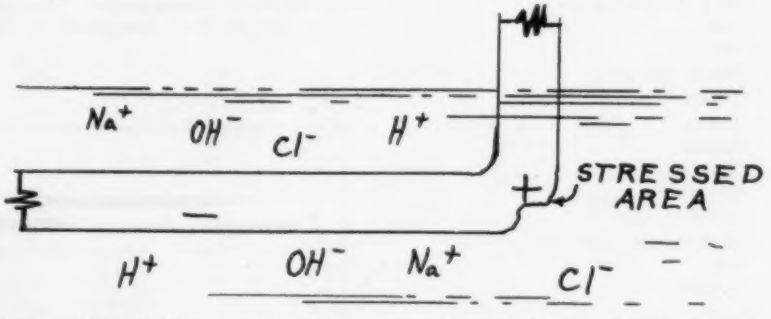

Fig. 3—BATTERY action caused by difference in environment between different places on the same metal

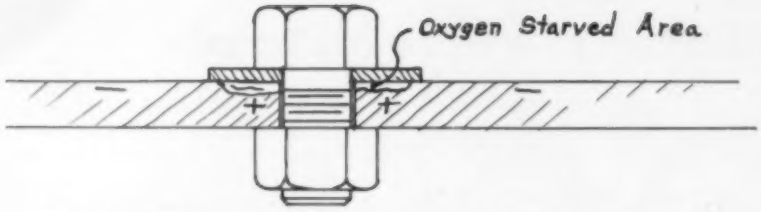

Fig. 4—OXYGEN concentration cell caused by lack of oxygen under tight washer

Fig. 1, but the action is the same. The positive metal, the anode, goes into solution and a current flows between the two metals. Again it is the anode which is destroyed.

Of the three presented, Fig. 3 illustrates the most difficult case to diagnose and understand. Here, only one kind of metal is involved, but because of a difference in environment from one place on the metal to another place, one of them is anodic to the other and a "battery" action results. Again it is the anodic area which is destroyed.

What, then, are the essential requirements for a galvanic cell?

1. There must be two areas at different voltage levels (potentials) so that a current will tend to flow between them.

2. The two areas must be connected by an electrical conductor.

3. The two areas must be submerged in an electrolyte, a conducting solution.

Table 1 shows the galvanic series.

TABLE I
The Galvanic Series

Anodic (+)
Magnesium
Magnesium alloys
Zinc
Aluminum 2S
Cadmium
Steel or iron
18-8 Stainless (active)
Lead
Tin
Nickel (active)
Brasses
Copper
Bronzes
Copper—nickel alloys
Monel
Nickel (passive)
18-8 Stainless (passive)
Silver
Graphite
Gold
Cathodic (—)

In this series the metals are so arranged that any metal is anodic to those appearing below it in the list and cathodic to those above it. Therefore, if a metal high on the list is connected to a metal low on the list, the higher metal will be destroyed by galvanic cell action. Rule No. 1, therefore, is:

DO NOT CONNECT METALS HIGH IN THE GALVANIC SERIES WITH METALS LOW ON THE GALVANIC SERIES.

It will be recalled it was said that the current "left" the anode and the anode went into solution. If a small anode were coupled with a large cathode, the current density at the anode would be much greater than that at the cathode, since the total current leaving equals the total current entering. Therefore, the small anode would dissolve at a much greater rate than if the anode and cathode were the same area. Thus, Rule No. 2 is:

IF YOU CANNOT AVOID A GALVANIC COUPLE, DO NOT COUPLE SMALL ANODES WITH LARGE CATHODES.

This discussion so far is quite fundamental and it would seem obvious that the way to avoid a galvanic cell action would be to avoid galvanic couples. For the most part, this has been done by manufacturers of water works equipment, particularly water meters.

Why is galvanic corrosion still a problem?

It was stated that galvanic corrosion occurs in many forms. The galvanic couple just described is the simplest. In addition to it, oxygen concentration cells, metallic ion concentration cells, differential aeration cells, crevice corrosion, and intergranular corrosion are typical of other specific types of galvanic corrosion.

Fig. 4 shows a schematic section through an oxygen concentration cell. The washer under the bolt prevents the free access of the liquid to the metal beneath it, while the metal outside the washer is freely bathed in the liquid. Thus the metal beneath is oxygen starved compared to the remainder and becomes anodic to it. The result is a pitting type corrosion beneath the washer. This general type of action also can occur whenever there is an oxygen concentration differential, such as a lap joint between metal sheets or a crevice between two cast parts, etc. Oxygen concentration cell action is characterized by pitting below the shielding object, be it a deposit, a sheet metal lap or a crevice.

A typical metallic ion concentration cell is shown in Fig. 5. In this type

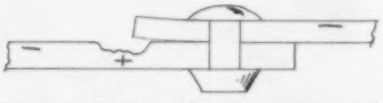

Fig. 5—METALLIC ION concentration cell at crevice of plate lap

of cell the action is analogous to the oxygen concentration cell except that an excess of metallic ions build up in the crevice and a galvanic cell action ensues. The attack takes place at the edge of the crevice. Metallic ion concentration cell corrosion can sometimes be differentiated from oxygen cell attack by observing the location of the degraded area.

Differential aeration and crevice are two terms meaning virtually the same thing as oxygen concentration. Since it is the oxygen in the air which is responsible for the attack, a difference in concentration of air dissolved in the liquid between two areas will result in an oxygen cell action.

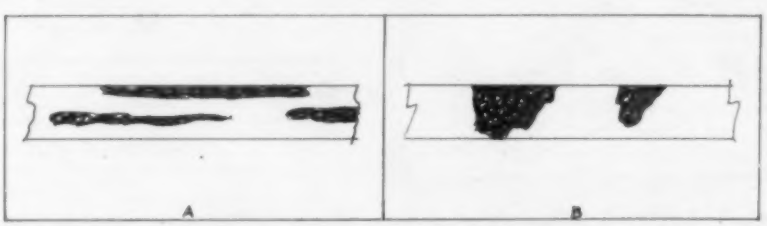

Fig. 6—DEZINCIFICATION may be of the layer type (left) or the plug type (right)

Intergranular corrosion is the result of a difference in composition the grain boundary areas and the center of the metallic crystal. The grain boundary areas are anodic to the crystal as a whole, with the result that these areas are degraded. The only solution to this problem is proper alloy selection and proper treatment of the alloy to obtain the desired microstructure.

Direct chemical attack is not liable to be a major problem in water service metering. This form of corrosion is characterized by a direct chemical union between one or more of the metal constituents and some element in the water to form a chemical compound. It is, of course, possible that some contaminants in a potable water supply might give rise to this form of attack, but it is not considered to be in contact long enough to cause trouble.

Dezincification is a type of attack specifically associated with the brasses. It occurs in brasses containing more than 15 per cent zinc and is not apt to occur in water meter practice because most manufacturers use an alloy with lower zinc content.

Dezincification is characterized by the apparent removal of the zinc from the alloy leaving a weakened honeycomb structure of copper. It occurs in two forms; layer and plug type. Layer type attack takes quite a long time to render the material useless. Plug type attack can proceed through a material and cause leakage in a relatively short time (see Figs 6A and 6B).

Erosion and impingement attacks are mechanical in nature and are due to liquid moving at relatively high velocity and striking the surface of the material. Actually, erosion and impingement are used to describe two degrees of basically the same action. Impingement is used to describe the damage done by moderate velocity liquid whereas erosion describes the action of high velocity liquid.

The attack of the metal is not one of the basic metal itself being removed by the impact of the stream of liquid on its surface. The liquid stream actually removes softer corrosion products from the surface, thus re-exposing bare metal to new corrosive action. If the corrosion product films were left on the surface, chances are they would stifle further attack. The action can be thought of as an alternate corroding of the metal followed by washing out of the protective films. This cycle is repeated time after time with resultant penetration into the metal surface.

Fig. 7—CORROSION and impingement attack shows characteristic directional pits

Corrosion and impingement attack is characterized by directional pits, elongated in the direction of flow, and evidencing an undercut lip on the downstream side of the pit (see Fig. 7).

Fretting corrosion is associated with close mechanical fits between mating parts and vibratory motion. The vibration is thought to break down protective films and allow corrosion to proceed in the crevice between the parts. It is characterized by pitting and results in loss of dimensional accuracy and strength of parts affected.

Corrosion Mitigation

Most of the work in corrosion investigation has already been done by the water meter manufacturer in proper selection of alloys and attention to design details so as not to create situations favorable to corrosive attack.

However, due to the vast differences in potable waters throughout the world, it is not economically feasible to manufacture one universally applicable meter. Couple this to seasonal variations in water analysis in some locations and the problem becomes highly complex. In many cases it is necessary to run tests to determine what alloys may best be utilized.

One of the important factors to be considered in reducing water meter corrosion is the dissolved oxygen concentration. Copper-base alloys are particularly sensitive to corrosion in liquids high in oxygen content.

Certain elements in water which would not be considered to have ill effects on human beings might give trouble from the corrosion standpoint. Some metal salts, such as ferric chloride or ferric sulphate, will hydrolize and form weak acids, which will attack the copper-base alloys. Sulphides are particularly corrosive to the higher copper alloys. Traces of these elements can be picked up by the water at its source, particularly ground waters, and may not necessarily be removed by water treatment.

Although dissolved carbon dioxide would be expected to be more harmful to higher zinc content alloys than those used in water meters, the CO_2 content of the water should be kept at a minimum. There is always the possibility that high dissolved CO_2 content will attack even water meter alloys.

Chlorine and chloride salts are very corrosive to copper-base alloys. It is possible to pick up either of them in the water supply and cause attack. Meter parts analyzed in Badger's laboratories have shown chlorides to be part of the corrosion product residue.

It can be seen from this brief discussion that corrosion mitigation is not only a matter of selecting and correctly applying alloys, but it is also a function of properly conditioning the water to eliminate the highly active elements which cause corrosion.

CORROSION IN SEWAGE WORKS*

by EDWIN R. STOWELL

Senior Sanitary Engineer, California State Division of Architecture, Sacramento, Calif.

NEGLIGENCE in the control of corrosion frequently has been due to a lack of knowledge in understanding the corrosion factor. Specific instances may be observed where abnormal or excessive deterioration of plant structures or equipment has occurred, due primarily to corrosion. In many cases this has taken place without the operating personnel recognizing that corrosion was active.

It is not anticipated or expected that all sewage treatment plant operators will become corrosion experts.

In support of the premise that the role of corrosion may be overlooked in the wear of equipment, a section of sludge scraper chain was removed from a primary clarifier. Inspection revealed that one side of the chain had been worn or corroded to a thin knife-edge section, while the other side had retained its original cross section. This rather familiar "wear" pattern of scraper chains is considered by many operators to be due solely to mechanical wear. The condition, however, is largely a result of corrosion forces, possibly in combination with erosion or mechanical wear, whereby new metal is constantly being exposed to corrosion. The important point is not that this excessive and localized loss of metal occurred, but rather that the operator did not observe or consider anything unusual in the wear. That is, he did not recognize the corrosion factor.

Examples of Corrosion

Corrosion is not always so readily noticed. In some forms of corrosion, the original shape and form of the material is retained despite severe corrosion. A section of cast iron drain line was obtained after clogging of the line had been reported, due supposedly to soap and greases. From an observation of the deposits in the pipe, it was apparent that the clogging was primarily due to corrosion products. Portions of the pipe section revealed shiny metal while other parts were black and dull. In the black, dull areas the metal had been completely corroded from the iron-graphite material leaving only the graphite. This graphite has little structural strength and can be easily cut with a knife. This is graphitization, a corrosion associated with gray cast iron.

The yellow brasses have a similar specific type of corrosion called dezincification. In material failures due to dezincification, the zinc is corroded from the brass leaving only the copper portion of the zinc-copper alloy. This is readily detected by filing as the copper color of the dezincified area sharply contrasts with the yellow brass color of the alloy. The dezinicified metal has little strength or resistance to wear and the result is failure.

Idle equipment often is neglected and damaged by corrosion. Frequently such corrosion is greater than if the equipment was in use. Equipment that is operated normally presents conditions less favorable to the condensation of moisture and the accumulation of moisture retaining corrosion products. Variations in temperature cause an expansion and contraction of air expelling the warm air during warm periods and drawing in cold air as cooling occurs. This may result in the condensation of moisture from the air on internal parts of equipment and their subsequent corrosion. This is particularly true of equipment installed out of doors. A good example of this condition might be evidenced by sewage pumps that have been installed for some time, but have not been finally connected or operated. The solenoid oiler reservoirs were actually full of water inside the glass enclosures due to condensation of moisture from the air.

Other examples of corrosion damage which have been noted include corrosion of aluminum pump frames, comminutor drums and cutters, motor bearings and the rusting and pitting of exposed metal. Damage to concrete, due to septic sewage conditions; the blackening of paint caused by hydrogen sulfide fumes; the rusting of electrical switching enclosures, due to high relative humidity; the corrosion of sludge scraper blades and similar items are indicative of the relentless toll in damage and costs attributed to corrosion factors. Quite often excessive deterioration of wearing parts is due principally to corrosion, because the semi-protective corrosion products are constantly removed, thereby exposing bare metal.

In general, it may be said that where any abnormal or excessive deterioration occurs, corrosion is a possibility. Rusting, pitting, tubercules, discoloration of metal or an adjacent structure, the thinning of metal or similar visual evidence are the most obvious means of detecting corrosion. Certain specific conditions are usually necessary before corrosion will occur. A knowledge of these conditions is perhaps the best means for detecting corrosion before damage occurs.

Conditions for Corrosion

At normal temperatures, moisture is necessary for corrosion. Therefore, damp humid locations or enclosures where condensation occurs should be given careful attention. Listed among these enclosures are automatic bar screens, electrical panel boards, sewage lift stations, wet pits, ventilating stacks and housed areas through which sewage flows. Submerged equipment and structures also are prone to corrosion.

Oxygen is also necessary for continued corrosion, except when low pH conditions prevail. Therefore, greater possibilities for corrosion may exist following oxidation type treatment processes.

Different metals which are in contact with sewage or the soil act as an electric battery, resulting in electrolysis. The extent of this corrosion depends on various factors including the metals involved and the relative areas exposed. If the exposed area of the more corrosive metal is small in relation to the less corrosive noble metal, the corrosion is apt to be severe.

Differences in the environment of a metal also may result in electrolysis. Differences in velocities of flow, dissolved solids or liquids may be among the many environmental conditions which can cause corrosion due to electrolysis. Variations in oxygen content of a liquid produces a particularly corrosive situation. For example, the upper portion of the water seal of a floating gas holder contains more oxygen than the lower portion. Corrosive conditions exist along the line of contact of water containing oxygen and that devoid of oxygen.

Other conditions favorable to corrosion include increased temperatures, unequal stresses, increased flow velocities, bacterial action, crevices, acid conditions and stray electric currents. In fact any condition creating differences in the environment or causing the removal of protective corrosion products will favor corrosion.

*Reprinted from *Sew. & Ind. Wastes*, Vol. 28, No. 3, p 328 (1956)

Control of Corrosion with Lime

A review of basic principles and practical experience in corrective treatment of aggressive waters

by EDWARD S. HOPKINS

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IT IS common knowledge that soft water containing dissolved oxygen and free carbon dioxide corrodes iron and steel pipe excessively. In accordance with the electro-chemical theory, oxygen is the direct corroding agent; with the *rate* of corrosion governed by the reaction between the dissolved oxygen in the water and the film of atomic hydrogen at the surface of the metal. It is also known that the hydrogen ion concentration of the water is not a factor in the initial deposit of rust on clean or bright iron surfaces, since the initial rate of deposit is about equal at pH values between 5.0 and 9.0. After the initial rust coating has been deposited, continued corrosion of the metal is in direct proportion to the porosity of this coating. Rust coating deposited on pipe walls from waters containing "aggressive" carbon dioxide is porous, while that laid down in alkaline waters is compact and dense. Compact coatings of iron oxide and calcium carbonate will prevent diffusion of the dissolved oxygen in the water to the metal.[1]

"Aggressive" carbon dioxide was the term employed by Tillmans[2] to describe the corrosive action of carbon dioxide dissolved in soft waters having low pH values. Massink and Heymann[3] demonstrated that the aggressiveness of the carbon dioxide is regulated by the total bicarbonate alkalinity and pH of the water. To measure the aggressivity of carbon dioxide bearing waters, von Heyer developed the "marble test," now used as standard procedure.[4]

Cold Water vs Hot Water

Neutralization of aggressive carbon dioxide by alkali retards cold water corrosion by stoichiometric reactions and by the precipitation of the dense iron oxide-calcium carbonate coating on the pipe surface. It is, therefore, an indirect method of control when the pH value is continuously maintained at the calcium carbonate saturation point. The disappearance of "red" water denotes a sufficient control for practical purposes. The *rate* of corrosion in iron pipe lines is in direct ratio to the reduction in dissolved oxygen in the water during passage through the system. Routine testing for dissolved oxygen is the best criterion to determine the extent of corrosion and, conversely, the efficiency of the corrective treatment.

Hot water corrosion, in relation to steam generation, is not eliminated by

TABLE 1

Monthly Average of pH Value Water Leaving Montebello Filters

Month	1953	1944-1950
January	7.8	7.8
February	8.0	7.9
March	8.0	7.9
April	8.0	7.9
May	7.8	7.8
June	8.0	7.8
July	7.9	7.8
August	7.8	7.8
September	7.7	7.9
October	7.9	7.9
November	8.0	7.9
December	8.0	7.8
Average	7.9	7.9

TABLE 2

Monthly Average of pH Value—1944-1950 Water in the Distribution System, 47 Weekly Samples

Month	First Zone	Second Zone	Third Zone	Fourth Zone	Fifth Zone
January	7.5	7.5	7.3	7.3	7.3
February	7.5	7.5	7.3	7.3	7 2
March	7.6	7.6	7.3	7.3	7.3
April	7.6	7.7	7.3	7.3	7.3
May	7.6	7.5	7.3	7.3	7.3
June	7.6	7.6	7.3	7.3	7.2
July	7.6	7.6	7.3	7.3	7.2
August	7.6	7.6	7.3	7.3	7.3
September	7.5	7.5	7.3	7.3	7.3
October	7.5	7.6	7.3	7.3	7.3
November	7.6	7.6	7.3	7.3	7.3
December	7.5	7.6	7.3	7.3	7.3

*Formerly, Principal Assoc. Sanitary Engineer, Baltimore, Md.

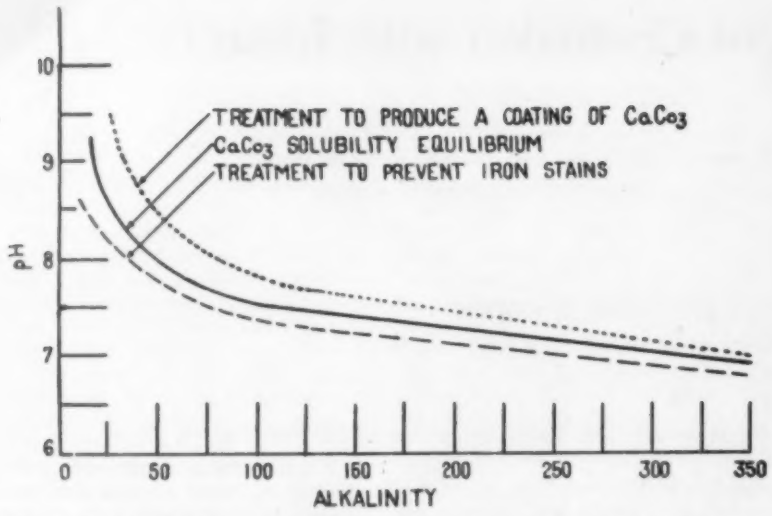

Fig. 1—Relationship between alkalinity, pH, and calcium carbonate solubility

this treatment, since the bicarbonate ion is formed by the neutralization of the free carbon dioxide. Upon heating the water to boiling, the bicarbonate ion breaks down to free carbon dioxide and hydroxide, frequently producing corrosion in return condensate lines. Treatment at the steam generating plant is required to overcome this condition.

Treatment of Very Soft Waters

A soft water of less than 20 ppm (parts per million hardness) will have slight buffer action. Maintenance of the calcium carbonate equilibrium in this water through the addition of lime will require high pH values, resulting in caustic alkalinity. This is usually of minor importance to industry, but may be objectionable to the consumer in that it is apt to produce an unpalatable taste.

The Catskill water supply for New York City has a normal alkalinity of 8 ppm. Hale[5] reports that neutralization of the free carbon dioxide in cold Catskill water with lime raised the pH value to between 9.7 and 9.9; with 10 ppm excess calcium hydroxide the pH was 10.1; with 50 ppm it was 10.3-10.4; and with 100 parts per million it was 10.8. After 148 days, ¾-inch diameter black iron pipe was heavily coated by a soft sludge of calcium carbonate. Flow decreased as follows:

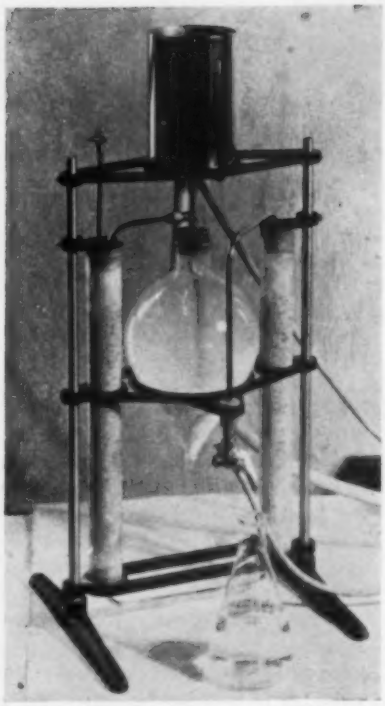

Fig. 2—ENSLOW continuous stability indicator

Untreated water	55 per cent
CO_2 just neutralized	35 per cent
10 ppm excess lime	20 per cent
20 ppm excess lime	15 per cent
30 ppm excess lime	10 per cent
40 ppm excess lime	6 per cent
50 ppm excess lime	8 per cent
100 ppm excess lime	16 per cent

It may be concluded from these flow data that high line treatment is not practical for this soft water without periodic cleaning and flushing of the system. With a gravity flow system, cleaning and flushing would not be expensive in comparison to the cost of pipe renewal. The introduction to very soft waters of substances intended to increase buffer action and lower the pH value to the point suitable for corrosion control is not usually economically advantageous. Unless cheap water is available for flushing, replacement of corroded pipe, due to its relatively short life, is the most practical procedure.

It is apparent, therefore, that lime treatment to eliminate corrosion has

TABLE 3

pH Value during 1953—Average Weekly Samples
Effect of Alkali Treatment on Water in Outlying Zones

Month	Second Zone	Towson Reservoir	Third Zone	Fourth Zone
January	7.4	7.5	7.4	7.6
February	7.4	7.6	7.3	7.7
March	7.3	7.5	7.3	7.5
April	7.4	7.8	7.4	7.8
May	7.1	7.5	7.2	7.4
June	7.4	7.8	7.3	7.6
July	7.8	7.7	7.6	7.7
August	7.8	8.3	7.6	7.9
September	7.7	7.7	7.5	7.5
October	7.5	7.8	7.4	7.6
November	7.4	7.6	7.3	7.4
December	7.3	7.4	7.3	7.5
Average	7.5	7.7	7.4	7.6

its greatest value with waters having a hardness greater than 25 parts per million.

Treatment Guides and Plant Control

Baylis[6] in 1922 initiated pH controlled corrective treatment with lime as a function of water purification, using the Gunpowder River supply at Baltimore, Md.

This river water is moderately hard, having the following average analysis:

Alkalinity	35 ppm
Soap hardness	38 ppm
Bicarbonates	43 ppm
Sulfates	7.9 ppm
Free carbon dioxide	6 ppm
pH	7.1 ppm

To facilitate plant operation Baylis[7] studied the solubility of calcium carbonate under varying conditions of pH value and total alkalinity and prepared curves revealing the calcium carbonate saturation point under these various conditions. Fig. 1 reveals these values and serves as a practical guide. These curves show, for instance, that with a total alkalinity of 50 ppm or less, a pH of 8 or more is required to obtain calcium carbonate saturation.

Enslow[8] developed a continuous corrosion or stability indicator which maintains a constantly flowing sample of water at the calcium carbonate saturation point. This device (Fig. 2), permits testing for the correct pH and alkalinity of the treated water as often as desired, and without laborious and time consuming operations. Usually this device provides a 4-hour contact period with the powdered calcium carbonate. Sampling of the water after passage through the stabilizer determines both the saturation point and criteria for plant control.

The value of corrective treatment with lime or other alkali depends upon the *constant* maintenance of the hydrogen ion concentration (pH value) at the calcium carbonate saturation point, in order to maintain a thin but dense protective film. It cannot be an intermittent treatment, since at any time the water is below this pH value aggressive carbon dioxide is present and will redissolve the coating previously precipitated.

Accurate control of the lime dosage and precise pH values can best be accomplished by the use of recording potentiometers. These devices (Fig. 3), usually are actuated by glass electrodes, sensitive to pH values from 2.0 to 12.0. The charts used on the potentiometer (Fig. 4), serve as a permanent record of the pH value of the delivered water and history of treatment. This equipment is inexpensive and trained technical skill is not required to keep it in good order.

Commercial dry feeders and other appliances are avilable for the application of lime to a water supply. Either high-grade pebble caustic or hydrated lime may be used. The larger water treatment plants find the caustic lime to be most economical when continuous dry feede s and slackers are utilized.

Results of Lime Treatment

Once calcium carbonate equilibrium has been established, the water will remain stable, and the effect of lime treatment is apparent in pipe lines after a few months. For example, the calcium carbonate solubility point for the Gunpowder River water at Baltimore is at pH 7.8 with an alkalinity of 38 ppm. It will be noted[9] in Table 1 that the pH value of the water leaving the Montebello filters for the period 1944-50 averaged 7.9, and this characteristic was maintained during 1953. It is apparent that the water entering the distribution system has been continuously maintained at the calcium carbonate saturation point.

Table 2, taken from a previous publication,[10] discloses that during the 1944 to 1950 period the average pH value of the water in the first zone was 7.6; in the second zone, 7.5; in the third zone, 7.3; in the fourth zone, 7.3; and in the fifth zone, 7.3. Water in the third zone system may be obtained directly from second zone pumps or by gravity from the third zone reservoirs, and may therefore be a mixture of these two sources.

To overcome this low alkalinity in the outlying zones, soda ash was applied to the water as it entered the Towson and Pikesville reservoirs feeding the third, fourth and fifth

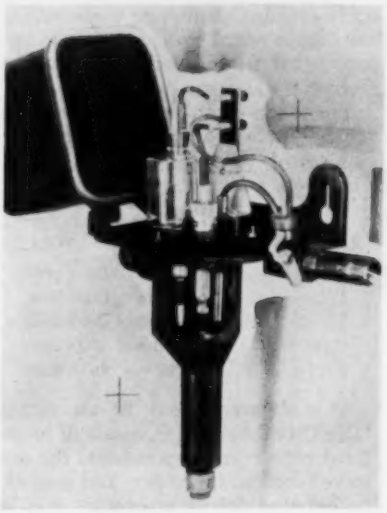

Fig. 3—TYPE of pH recording potentiometer

zones. The operation began in the latter part of 1952, using a commercial dry feeder. The soda ash is dropped directly to the surface of the water, dissolving and dissipating through the reservoir with the flow. This material was selected since it was recognized that the application of lime to a secondary reservoir would, in all probability, precipitate calcium carbonate on the bottom, resulting in an increase in algae growths.

Data from the Towson reservoir are more complete and this portion of the distribution system was selected for study.

As shown[9] in Table 3 the average pH value of the water delivered to the Towson reservoir, during the year 1953, from the second zone pumps was 7.5. Application of soda ash kept the water in this reservoir at pH 7.7 and in the fourth zone at 7.6. Water in the third zone averaged pH 7.4 due to the admixture of water as previ-

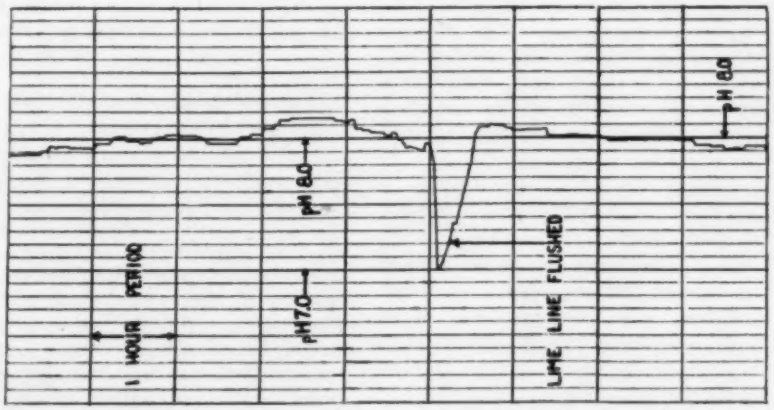

Fig. 4—SPECIMEN chart of pH values produced by recording potentiometer

ously noted. Contrasting these values with those noted in Table 2, it is apparent that the addition of alkali to the reservoir water was beneficial.

The soda ash treatment reduced "rusty" water complaints in the second, third, fourth and fifth zones. The iron content before and after treatment is as follows:

Zone	1944-1950	1953
1	0.03 ppm	0.03 ppm
2	0.06 ppm	0.04 ppm
3	0.15 ppm	0.07 ppm
4	0.13 ppm	0.03 ppm
5	0.27 ppm	0.15 ppm

It is apparent from the preceeding table that the addition of alkali in the third zone reservoirs reduced the dissolved iron in the water, and it is expected that future complains will be at a minimum.

About 3,587.02 million gallons of water per year, or 9.8 million gallons per day, was displaced in the Towson reservoir. Due to mechanical difficulties, the soda ash application was below standard in January, March and November. The minimum application was 0.49 ppm in November and the maximum 1.54 ppm in December. During the year, 37,800 pounds of soda ash were used, averaging 3,150 pounds per month. Records were kept on a monthly basis and daily dosage was not obtainable. Averaged monthly data corresponded to a daily application of 1.27 ppm.

The treatment is relatively expensive, but is considered to be justified since it has reduced the water wasted by weekly and other periodic flushing of the mains in these zones. The volume of flushing water was of considerable magnitude, amounting to several million gallons yearly. The soda ash treatment cost $1,582.43 in 1953, including depreciation of equipment and labor costs. This supplemental treatment is equivalent to a cost of $0.34 per ppm per million gallons to raise the pH from 7.5 to 7.7, and is in sharp contrast to the cost of corrective treatment at the filter plant which is $0.07 per ppm per million gallons to raise the pH from 7.1 to 7.9.

Summary and Conclusions

The principles of the electro-chemical corrosion of iron and steel pipe by low alkalinity waters containing "aggressive" carbon dioxide have been reviewed.

The fixation of aggressive carbon dioxide by adding the correct quantity of lime to water causes a dense, compact coating of calcium carbonate-ferric oxide to be deposited on the pipe walls. This coating, if of proper density, *prevents* the diffusion of the dissolved oxygen in the water to the hydrogen film on the iron, thereby retarding corrosion. Rust deposited when the water is below the calcium carbonate saturation point *permits* diffusion of the dissolved oxygen and does not check corrosion.

The treatment is not satisfactory for waters very low in alkalinity (10 ppm or less) since overly high pH values are required, depositing a soft fluffy sludge-like coating in the pipe lines. This sludge is porous and is sometimes of sufficient magnitude to retard flow.

A water maintained at the calcium carbonate saturation point has a stable hydrogen ion concentration, and the pH value usually is unchanged in passing through a closed distribution system. It is apparent that the maintenance of non-corrosive water in the outlying sections of a large distribution system which includes a series of open balancing reservoirs requires secondary treatment with alkali. For many reasons, caustic soda or soda ash is the compound of choice. The high cost of the treatment, $0.34 ppm per million gallons, is justified, since both periodic flushing of the system and consumer complaints are reduced to a minimum.

There is an extensive investment in iron and steel pipe in water systems; these pipe lines need protection against internal corrosion. Alkali treatment, preferably with lime since it is the cheapest compound, is economically justified with fairly corrosive water since corrosion costs greatly exceed treatment costs. Based upon public water supply experience, it is believed that corrective treatment with lime (and, when needed, with soda ash or caustic soda) will produce a water of considerable economic value to many industries.

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Tenth Edition of Standard Methods

A Comparison with the Ninth Edition

by THEODORE JAFFE

Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Ala.

EARLY in 1955, the tenth edition of "Standard Methods"[1] was released. This revision contained many changes in actual techniques of analysis, as well as changes in the presentation of the material.

The changes in procedures that the author thinks are most commonly used by sewage plant operators are pointed out in this article. It is not intended, however, that the changes discussed eliminate the need for a careful reading of the tenth edition by plant operators. Further, it is most emphatically recommended that a copy of this edition be available at every sewage treatment plant.

Industrial Wastes Section

One of the first changes to be noted is that of a separate section of analytical procedures for industrial waste analyses. Since these wastes often require special analytical treatment, the plant operator should become familiar with this section, even if only to be aware of this special attention.

In addition, a procedure used in domestic sewage analysis often needs some modification before it can be applied to an industrial waste. For example, most plant operators know that before a B.O.D. determination can be run on a chlorinated effluent, the sample must be "seeded"; that is, microorganisms must be put back into the sewage to replace those killed by the chlorine.

For similar reasons, an industrial waste may need to be seeded because of some killing substance it may contain, or its pH may need adjusting, or some other change in the routine procedure may be required. These changes are contained in this section on industrial wastes, as well as specific methods for substances not usually found in domestic sewages (for example, the heavy metals, phenols, and others).

Guide to Method Choice

The tenth edition has preceded each analytical procedure with a brief discussion of the method. Where more than one method is given, some guidance is offered the operator as to which procedure should be used. In the past, where several methods were listed, it had been difficult to decide which to use for a particular sample. To help overcome this difficulty these discussions point out the shortcomings of each method, the quantity range within which the method is applicable, interfering substances, etc.

Tentative Methods and Instruments

Previous editions of "Standard Methods" had a section called "Non-Standard Methods." These were methods that were on trial. They had not been used long enough, or in sufficient situations to be accepted by the Standard Methods Committee. Such a procedure was placed in the book for a period of time and thereafter either accepted as a standard method, or discarded. In the tenth edition, these procedures are called "Tentative."

The use of instruments as analytical tools has increased tremendously in the last few years. This latest revision of "Standard Methods" has followed this trend by suggesting the use of instruments in many procedures. These are mainly used in places where differences in results may easily arise due to the human factor. For example, in determining the amount of nitrite nitrogen present in a sample, the analyst finally has a Nessler tube filled with a reddish-purple liquid. If this sample were given to five persons and each person visually compared his tube with the same set of standards, you would probably get five different results. Each person would honestly match the sample and standards differently, solely due to his individual response to the colors. If by some chance a person were color blind, he would not be of much use as an analyst. It is in overcoming these individual differences that instruments have great value.

In the tenth edition, for the nitrite determination a spectrophotometer, a filter photometer or visual comparison, in that order, are listed for reading the reddish-purple color. Similarly, the use of instruments is recommended for many other procedures; for example, pH meters instead of colorimetric pH readings, determining the end point in a titration of acidity or alkalinity using a potentiometer (pH meter) instead of by the color change, amperometric

determination of residual chlorine, etc.

Reporting Results

Although the tenth edition does not definitely say so, it is readily apparent that the planners of this edition would like to see all analytical results expressed as milligrams per liter (mg/l) instead of parts per million (ppm). To most plant operators, and for most purposes in sewage treatment, these units are the same.

Strictly speaking, though, they are not. Parts per million is a way of expressing a weight relationship; it means one part by weight in a total of one million parts by weight. When one milligram of a salt is dissolved in one liter of water at 4°C the concentration can be expressed as either one milligram per liter or as one part per million. Here, either expression is correct because one liter of water weighs 1,000 grams (kilogram), and since 1,000 grams is equivalent to 1,000,000 mg, there is 1 mg of salt in 1,000,000 mg of solution. This expresses a weight to weight relationship, in the same units, of 1 to 1,000,000, which is one ppm. Therefore, when dealing with water the two expressions, ppm and mg/l, mean the same thing. However, with some sewages, and especially with many industrial wastes, this is not true.

The important idea in the preceding discussion is that one liter of water weighs one kilogram only at 4°C. If one liter of the dissolving substance or the carrying substance weighs more or less than one kilogram, then ppm are not equivalent to mg/l. To be exact, one liter of domestic sewage does not weigh one kilogram, but a little more. For most purposes, it is assumed that one liter of water and one liter of sewage weigh the same. To say this another way, the specific gravity* of domestic sewage is assumed to be 1.0. For some sewages and some industrial wastes the specific gravity will be greater or less than 1.0. When this is so, ppm is not equivalent to mg/l, and any analytical results should be expressed as milligrams per liter with the specific gravity reported.

In line with the reporting of results, operators should become accustomed to the use of "significant figures." These are important whenever any results are reported, for it tells any person reading the results which of the figures in a number are meaningful. For example, if a report showed 6.000 ppm of SO_4, did the analyst mean 6 ppm, 6.0 ppm, 6.00 ppm, or 6.000 ppm? If the value of 6.0 ppm was justified, it would be misleading to report 6.000 ppm, for it implies a measurement that was not made. Since this topic cannot be covered adequately in a short article, the operators are referred to the discussion (and bibliography) on pages 23-28 of the tenth edition. A thorough discussion and practice period on "significant figures" should make a good topic for a short school!

The foregoing topics reflect most of the new thinking on general analytical methods for sewage as expressed in this edition. Specific differences, changes in techniques or procedures, and new methods are pointed out later. All page reference are to the tenth edition of "Standard Methods."[1]

It is well to restate here the advice on page 221 that before selecting a method of analysis, the operator should know whether or not his sewage contains any industrial wastes. If these are present, the methods listed in Part III should be used.

Specific Tests

Oxygen Consumed (pp 332-335)

Operators running oxygen consumed tests should note the following changes:

1. The oxygen consumed test is now based upon the oxygen consumed from dichromate and not from permanganate. For many industrial wastes this will result in far different values.

2. If the samples cannot be run within a short time after sampling, they should be preserved by acidification with sulfuric acid to a pH of 2 or 3 (p 222).

3. Operators should read over the short discussion on page 332 as to the interpretation of the oxygen consumed test.

pH and Acidity (pp 226-228; 268)

For plants where the acidity of a sewage is determined, operators should note that the tenth edition again recognizes two kinds of acidity —"free" acidity and "total" acidity. The determination of total acidity is exactly the same as previously; that is, titration to the phenophthalein end point. However, free acidity is that determined by titration with a standard sodium hydroxide solution to the methyl orange end point, and is run before the total acidity, or on a separate sample. These two types of acidity are familiar to water plant chemists and operators.

The idea of free acidity assumes, of course, that the pH of the sample is less than 4.0. If it were not, free acidity would not be present. Similarly total acidity assumes a pH less than 8.0, or else no total acidity (nor any free acidity) is present. Above pH 8.0, the sample will contain alkalinity, which can be determined as on page 228. These relationships are shown in Fig. 1.

Operators should note that a potentiometric titration method is included (page 227) for both alkalinity and acidity determinations. The method uses the glass electrode pH meter that is found in most laboratories. It is especially valuable for turbid or colored sewages or industrial wastes, where it would be difficult to see a colored end point.

In the foregoing the terms pH, acidity, and alkalinity have been used. To most persons the difference between acidity and alkalinity is fairly clear. The acidity of a sewage is the measurable amount of acid (hydrogen ions, H^+) available on titration with an alkaline solution to a definite end point. The alkalinity of a sewage is the measurable amount of alkali (hydroxyl ions, OH^-) available on

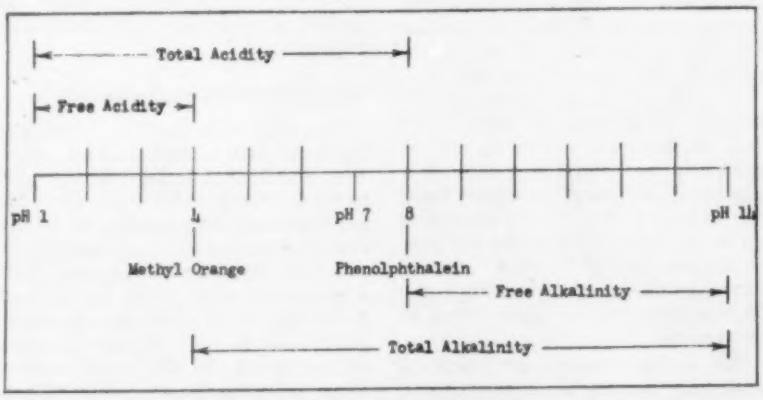

Fig. 1—Acidity and alkalinity relations

*Specific gravity is the ratio of the weight of a given volume of a substance to the weight of the same volume of water.

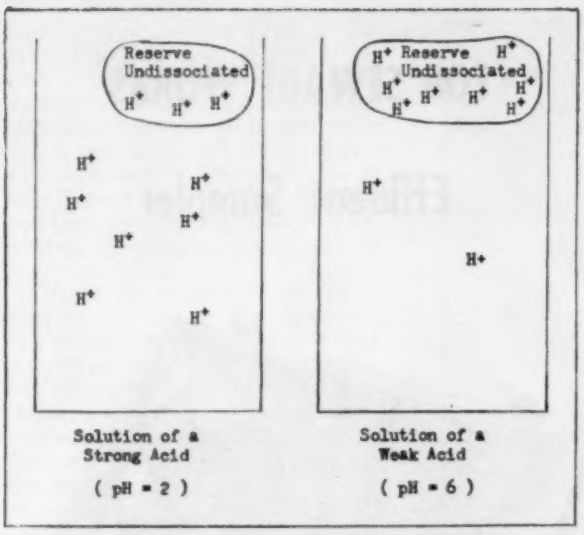

Fig. 2—pH of a strong and a weak acid

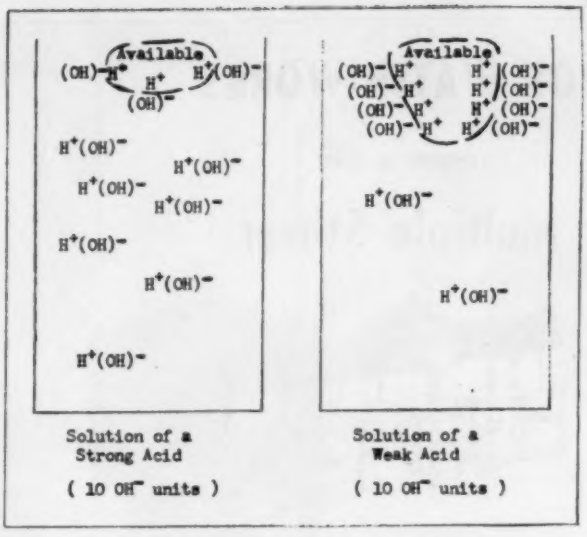

Fig. 3—Acidity of a strong and a weak acid

titration with an acid solution to a definite end point. Most persons know, too, that in a neutral solution the hydrogen ions and the hydroxyl ions are present in equal concentrations and that the pH of such a solution is 7.0.

However, one of the most puzzling subjects in water and sewage analysis is the distinction between pH and acidity, or pH and alkalinity. One author states that "pH is an *intensity* factor, expressing the *existing* concentration of the hydrogen ions, H^+. Acidity (like alkalinity) is a *capacity* factor and may be defined as the capacity for neutralizing base (or acid)."[2] To explain and illustrate these ideas one must be aware of the fact that acids and alkalies can be classified as weak or strong. Hydrochloric and sulfuric acids, sodium and potassium hydroxide are strong; acetic acid and ammonia are weak. This means that a solution of a strong acid or alkali produces (dissociates into) a relatively large number of hydrogen or hydroxyl ions with relatively small amounts of acid or alkali held in reserve (undissociated). With the weak acids or alkalies the reverse happens—most of the acid is held in reserve, with a relatively small amount dissociating immediately in solution. This is illustrated in Fig. 2.

The determination of pH is the measurement of "the existing concentration of the dissociation products, representing an intensity term. It is the *effective* reaction, at present existing, regardless of the *latent* reaction which comes into play only when neutralization is attempted."[3] Again referring to Fig. 2, one can see that the acid on the left has dissociated to a greater degree than that on the right, thus producing more hydrogen ions. Since more hydrogen ions are immediately present, the pH of the left solution is lower (pH2) than that on the right (pH6).

It can be seen in Fig. 2 that the total number of hydrogen ions in each solution is ten. On the left, seven hydrogen ions are dissociated, with three remaining undissociated. On the right, only two hydrogen ions are dissociated and eight remain undissociated. If each of these solutions were titrated with an alkali to the same end point, each would require the same number of milliliters of the alkali. This is so because there is a total of ten hydrogen ions available in each of the solutions, and these require ten hydroxyl ions for neutralization. Since the hydroxyl ions come from the dissociation of the alkali, each of the solutions will require the same amount of alkali to reach the same end point. This is illustrated in Fig. 3. The amount of alkali required to combine with the total hydrogen ions in a sample measures the acidity. The amount of acid required to combine with the hydroxyl ions of a sample determines the alkalinity.

From the foregoing discussion it should be evident that although one sewage sample has a pH of 2.5 and another a pH of 5.8, both may contain the same amount of acidity. Similarly, although one sample may have an alkalinity of 120 ppm and another sample have 420 ppm of alkalinity, it is possible that the pH of both samples may be the same.

Before leaving this topic, the author wishes to point out that item (d) p. 268, on the care of pH electrodes, in his opinion, is not the best procedure. The glass electrode may be kept in distilled water when not in use, but a calomel electrode should not. When not in use, it should be covered with the rubber tip generally furnished by the manufacturer. If it is kept in water, diffusion will take place, and the electrode will soon become unusable.

Residual Chlorine (pp 229-234)

The determination of a chlorine residual with orthotolidine has often been difficult, if not impossible, with turbid or colored effluents. If the operator had the time and the skill, he would use the starch-iodide method. Even this method is worrisome because of interfering substances and a somewhat poor end point.

The tenth edition has retained these two methods for use where applicable and has included a new method—amperometric titration. Like the older two methods it has limitations. Its greatest advantage is that it is not subject to interference from color or turbidity. The method does not differ from the starch-iodide one in principle, but it does have a more accurate end point which is determined by observing a meter on the titration instrument (Fig. 4). Details of the method can be found on pages 229-231.

Chlorine Demand (pp 235-237)

The chlorine demand test has been replaced with the "chlorine requirement" test in this tenth edition. In the previous edition (ninth) the chlorine demand test was a rather

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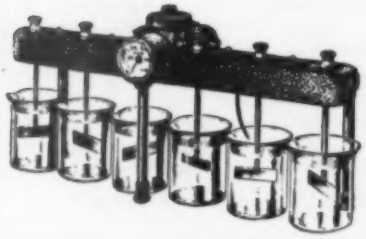

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rigid, definite test set down as follows: "The chlorine demand is the ppm of chlorine required to be added as chlorine water to produce a residual chlorine content of 0.1 ppm after *fifteen* minutes contact of the chlorine with the sewage."[4] Several changes in objectives of the test, procedure, and use have been made, as well as renaming the test as the chlorine requirement test.

One of the changes in the objectives of the test is the distinction that chlorine may be added to sewage for purposes other than bacterial control. The chlorine demand test was primarily aimed at a reduction in the numbers of bacteria in the sewage. However chlorine may be used in sewage treatment for many other purposes (for example, odor control, reduction of B.O.D.), on industrial wastes for various reasons, etc.

In these cases the old definition had very little meaning. Suppose for instance, that chlorine is to be used to control bulking in an activated sludge. The objective is to chlorinate to such a point that the sludge will begin to settle. If, as in the old demand test, the operator chlorinates to a residual of 0.1 ppm he probably will control the bulking, but may also find that he has killed his sludge. The point is that although chlorine can be useful in controlling bulking, a different set of standards, other than 0.1 ppm residual after 15 minutes, must be used as a measure of its effectiveness. The operator wants to know how much chlorine is required to do the job, but the job may vary from one occasion to the next, even though the information required—how much chlorine is needed—is the same. Therefore, the chlorine requirement test allows for changes in both the amount of residual and the contact time, *provided* any such changes are stated in reporting the results. It defines the chlorine requirement for purposes other than disinfection control as "the quantity of chlorine required to achieve the various objectives."[5]

In many instances of sewage disinfection it may be desirable to carry a chlorine residual for longer than 15 minutes, or a residual of more than 0.1 ppm may be necessary. Under the old chlorine demand test, the residual and the contact time were both fixed. If either or both had to be changed, how could an operator do this, and yet comply with the definition? In the tenth edition the chlorine requirement is defined as "the amount of chlorine in mg/l which must be added to a sewage to produce a chlorine residual of such strength that, after a definite contact time, the effluent will show a desired coliform density, . . .".[6] With this definition, variations in contact time or dose, or both, are allowed and recognized as being required in some instances.

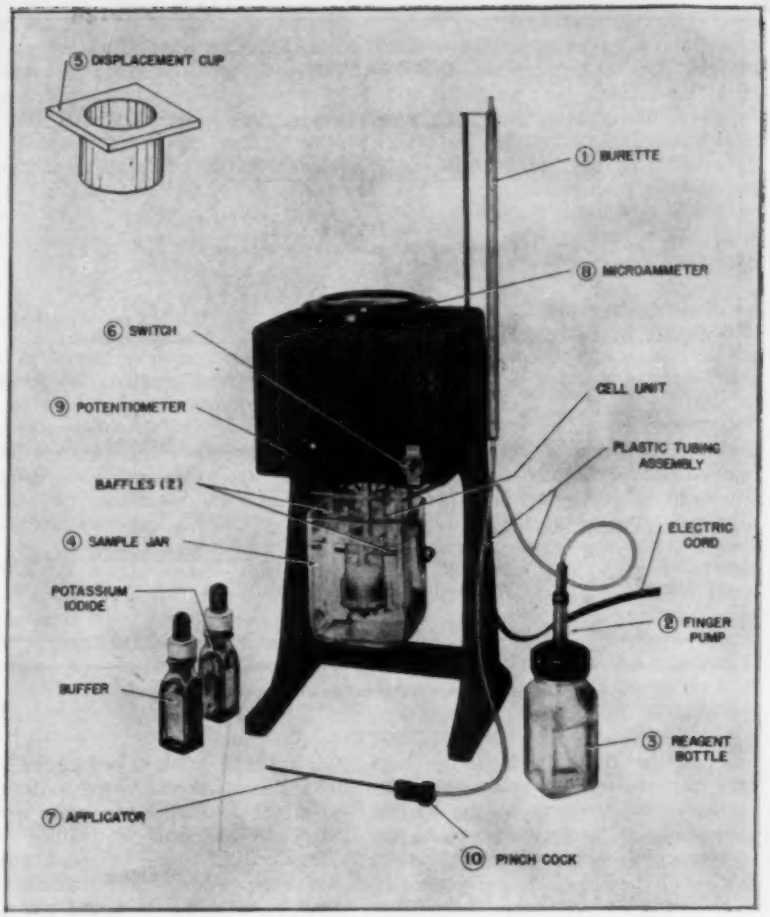

Fig. 4—Amperometric titrator

Grease (pp 238-239)

Although most sewage treatment plants do not run routine grease analyses, an operator may occasionally be called upon to perform this determination. The tenth edition has changed the method of grease analysis using the Soxhlet apparatus in one major detail. Instead of digesting the acidified sample by boiling, cooling, and then filtering, the new method filters the acidified sample without boiling. Furthermore, with this cold filtration method there is no need to add the filtrate to the Soxhlet thimble, as was done previously.

Since the foregoing method of grease analysis (Soxhlet extraction method) requires special equipment not usually found in a sewage plant laboratory, it has often been impossible to run such an analysis even if it were desirable. A new, tentative method called the Semi-Wet Extraction Method has been included in the tenth edition. The reagents required are the same, and the method is very similar to the Soxhlet, but the special Soxhlet extraction apparatus is not required. Whereas this method does not have quite the precision of the older one, this is overshadowed, in the author's opinion, by making it possible for more plants to run grease analyses, because special equipment is not necessary.

Nitrogen (pp 240-249)

The determination of the various forms of nitrogen found in sewages, industrial wastes, and plant effluents is a procedure that was commonly run in most plants before the acceptance of the B.O.D. test as a measure of the oxidizable organic material. Nitrogen, however, is only one of the organic compounds found in wastes, some others being carbohydrates, sugars, and fats. Because all of these (and many inorganic compounds) are used by the microorganisms in stabilizing sewages and

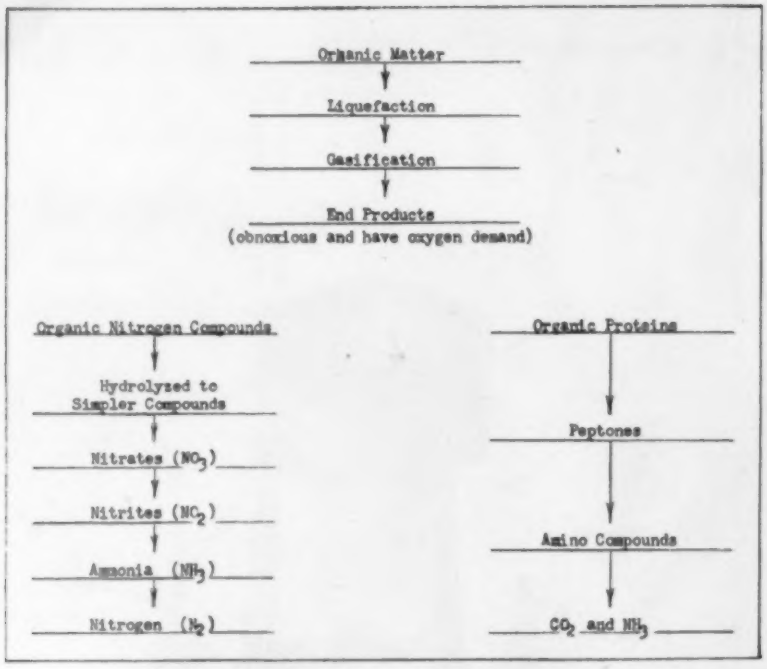

Fig. 5—Anaerobic stabilization of nitrogen compounds

wastes, the B.O.D. test, rather than the nitrogen tests, is now used to determine the strength of the wastes, the load on the treatment plant, the efficiency of the treatment process, etc.

However, a knowledge of the quantities of the different forms of nitrogen is still useful to the operator. For instance, in operating an activated sludge plant the amount and the ratio of nitrite and nitrate nitrogen is an indication of the degree of oxidation occurring in the aeration tanks. This is often a clue to possible bulking of the sludge in the secondary settling tanks. In many industrial wastes it is important to know how much nitrogen is present, for the microorganisms will not work efficiently if nitrogen is lacking. A certain ratio of nitrogen to carbohydrate is required for good performance (as, for example, in citrus wastes, where nitrogen must be added before secondary treatment will produce any effective B.O.D. reduction).

Since these nitrogen tests have some value in many types of sewage treatment it would be well to look into the changes in analytical methods made in this tenth edition. In determining the amount of ammonia nitrogen in a sample, the operator still has a choice of two methods—either direct Nesslerization, or distillation. The latter method is the more accurate and precise. No major changes were made in the direct Nesslerization procedure. The distillation method has had a titration procedure added, as an alternative to Nesslerizing after the distillation. In other words, after the ammonia is distilled over, the distillate may be read colorimetrically after Nesslerization, or it may be titrated with a standard acid.

For the nitrite nitrogen determination, a change has been made in the reagents. Previously an α-naphthylamine-acetate solution was used to buffer the reaction and bring out the reddish-purple color. In the new edition, two separate solutions are used —one of α-naphthylamine hydrochloride, and one of sodium acetate. Each of these is added to the sample individually and the color is then allowed to develop.

In running a Kjeldahl nitrogen or an organic nitrogen determination, two changes should be noted. First, phenolphthalein is used as an indicator when making the sample alkaline before distilling off the ammonia. The previous editions relied upon the blue color formed by the copper sulfate and sodium hydroxide. Second, the normality of the standard sulfuric acid has been changed from 0.05N to 0.02N. This change enables the operator to use the same standard acid for this determination as well as for alkalinity, eliminating the previous need for two standard acids.

Before leaving the matter of nitrogen analysis it would be well to point out certain relationships of the test. For waste treatment purposes we are usually interested in one or more of the following forms of nitrogen—ammonia nitrogen, organic nitrogen, nitrites, and nitrates. The amounts of these forms will vary from one waste to another, may change from day to day, and will change as the waste undergoes treatment. The course of stabilization of these nitrogen compounds is shown in Figs. 5 and 6.

To obtain the desired information about nitrogen, an operator would use the tests described in "Standard Methods." However, one of the most confusing things about nitrogen determinations is the use of the term "total Kjeldahl nitrogen." Actually, this test does not determine the *total* amount of nitrogen in a sample. It does determine the combined amounts of ammonia and organic nitrogen, but does *not* include the nitrites and nitrates. To obtain the amount of total nitrogen in a sample, one must run three tests—the Kjeldahl, the nitrite, the nitrate—and add these three results. To repeat, the sum of the organic nitrogen plus the ammonia nitrogen equals the Kjeldahl nitrogen.

Suppose one wanted to know how much organic nitrogen and ammonia nitrogen were in a raw sewage sample. "Standard Methods" gives the procedure for both of these tests. However, since the direct organic nitrogen determination requires very careful attention it is better, in most cases, to determine the organic nitrogen indirectly. This is done by running the Kjeldahl nitrogen on one portion of the sample, and the ammonia nitrogen on another portion. When these results are obtained, the organic nitrogen is calculated by subtracting the ammonia nitrogen from the Kjeldahl nitrogen results.

Dissolved Oxygen (pp 250-260)

The dissolved oxygen test and the B.O.D. test are two of the most commonly used analyses in waste treatment. Since the B.O.D. is actually a dissolved oxygen determination, correct procedure in running a D.O. is highly important if treatment plant results are to mean anything. Every operator should learn how to run D.O.; more than this, he should learn how to interpret his results. The test is a relatively simple one, but many substances interfere with accurate results. To correct for these interfering substances the basic D.O. test, called the Winkler method, must be modified, and seven modifications have been set down in the tenth edition. Depending, then, upon what interfering substances are present in the sample, the operator must choose his method. Of those listed, the last

two are new. These methods, with comments as to their use against specific interfering substances, are described on pages 250 and 251, and every person running D.O. and B.O.D. tests should read these over carefully.

In the actual running of D.O. tests, the tenth edition has increased the amount of manganous sulfate and alkaline KI solution used from 1 ml each to 2 ml each. Since the volumes of these reagents have been changed, the volume taken from titration corresponding to 200 ml of the *original* sample is changed. Previously the correction for displacement by the reagents was 201.6 ml. Now, however, it is 203 ml. This means that for the results of the titration with 0.025N thiosulfate solution to read directly in ppm or mg/l of dissolved oxygen, a portion containing 203 ml must be withdrawn from the acidified sample bottle of 250 or 300 ml. The formula for calculating this correction factor is on page 253.

One further, but very important note, is a correction that must be made on page 253, item 2.7. The amount of sodium thiosulfate used in making up the stock solution is incorrect. This should read 248.2 grams and not as stated. An official notification of this, as well as other corrections, will shortly be published by the Standard Methods Committee.

Biochemical Oxygen Demand (pp 260-267)

Every operator should carefully read this entire section on B.O.D. A large amount of new information has been included, and several important changes have been made.

The first of these changes is in the composition and the concentration of the buffer and fortifying solutions added to the dilution water. Since the dilution water is one of the most important parts of the B.O.D. test, these new directions should be followed closely to obtain standard results.

The seeding material to be used, where to use it, and how to correct for seeding in the final B.O.D. calculations, are discussed more fully in this edition. Since the B.O.D. test measures the amount of dissolved oxygen consumed by microorganisms in oxidizing the organic matter of a liquid waste, it requires the presence of these microorganisms. Without them there can be no B.O.D. If a waste has been chlorinated, or contains toxic substances, these may have killed off all or most of the microorganisms. In such cases, it is necessary to add new, live ones to the waste so as to obtain a depletion of oxygen and, therefore, a B.O.D. A waste may contain oxidizable organic materials and therefore have a potential B.O.D., but if the microorganisms have been killed, weakened, or greatly reduced in number, there will be no B.O.D. or an erroneous one. To prevent this, the dilution water is seeded as described on page 262.

Bacteriology (pp 359-410)

For those operators running bacteriological analyses, several changes in these procedures are noted. One of the new standards concerns the water used for dilution. This is now to be a buffered water, described on page 367. Tap water or distilled water alone cannot be used.

The medium to be used for plating out samples is tryptone glucose extract agar. Previously the analyst had a choice of three media for the standard plate count, but this has been changed to the one medium mentioned.

Under the discussion of the "Presumptive Test" (p. 375) sec. 1.3, a serious error has been printed. The time interval for a positive presumptive test is 24 ± 3 hours, and not 48 ± 3 hours as stated. This correction, as well as others, will be published, as previously noted.

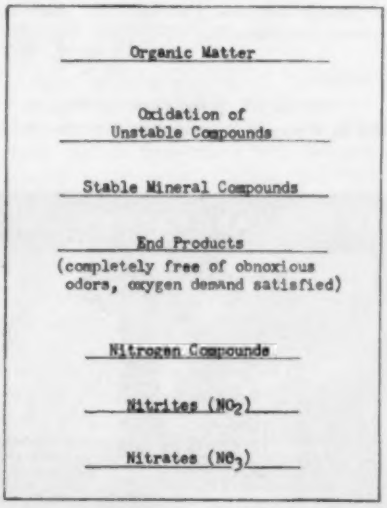

Fig. 6—Aerobic stabilization of nitrogen

One of the reasons that more plant operators do not run bacteriological examinations, is the amount of work involved. Previously, the operator had to run five tubes in each dilution so as to be able to use the tables for calculating an M.P.N. for his results. Some few, fortunate operators were able to get, or make up, a table based on only three tubes in each dilution. By so doing, the amount of work involved was considerably reduced. This new edition has included a table for determining the M.P.N. when only three tubes in each dilution are used (p. 386). Perhaps this will stimulate more sewage and water plant operators to run bacteriological examinations in their plants.

Users of the tenth edition will notice that the membrane filter technique for bacteriological studies has been included, but only as a tentative procedure. If any operators plan to use this, they must remember that it is not yet an accepted standard method. At present there is no method of correlating the results from the standard dilution tube procedure with those of the membrane filter. Therefore, if an operator switches to this technique his results will differ from those previously obtained, and may lead to confusion. "Standard Methods" definitely states that the membrane filter "cannot be considered an acceptable substitute for the dilution tube method."[6]

Summary

The foregoing comments and corrections are those that the author feels should be of greatest interest to sewage plant operators. There are other corrections, and other comments that could be made, but these should keep most operators busy for a while. Again, it should be stated that it is not intended for these few remarks to be a substitute for a copy of the tenth edition. Every sewage plant should have one of these invaluable books available for use by its personnel.

In the past year quite a few plants in various parts of the country have reported on sewage lagoons. The next article in this series will discuss this method of waste treatment.

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5. "Standard Methods," Tenth Edition, p. 237 (1955).

6. Ibid., p. 235.

7. Ibid., p. 395.

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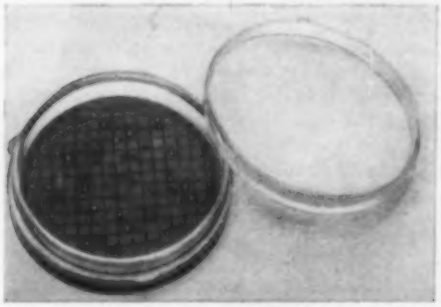

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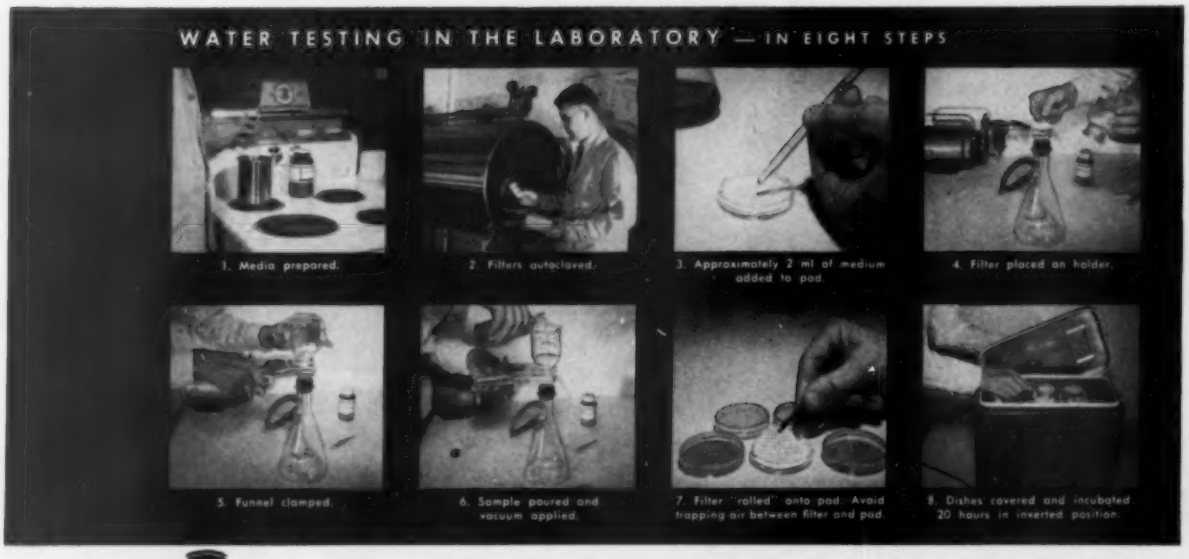
WATER TESTING IN THE LABORATORY — IN EIGHT STEPS
1. Media prepared.
2. Filters autoclaved.
3. Approximately 2 ml of medium added to pad.
4. Filter placed on holder.
5. Funnel clamped.
6. Sample poured and vacuum applied.
7. Filter "rolled" onto pad. Avoid trapping air between filter and pad.
8. Dishes covered and incubated 20 hours in inverted position.

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Appraisal of Membrane Filters

by ROLF ELIASSEN
Prof. San. Eng., Mass. Inst. Tech., Cambridge, Mass.

SOME OF THE GREAT pioneers in sanitary science and public health engineering—Sedwick, Phelps, Winslow, Levine and Streeter—who preceded the author in the Sanitary Science laboratories of M.I.T., would have "given their eye teeth" for an accurate and direct method of evaluation of bacterial numbers in a sample of water. Plate counts, decimal dilutions for the Phelp's Index, and finally the "M.P.N." technique were gradually made available as controls of water quality. As most sanitary engineers know, these are in reality crude statistical approaches to the *real* number of organisms in a sample of water. Now, for the first time in history, sanitary science has a simple, accurate, and precise method of potable water analysis in the membrane filter technique[1].

A Background of 10 Years

The highest scientific body in our country, the National Academy of Science, has had assigned some of its scientific talent on the development of the membrane filter technique over the past ten years. As a result of this work far more accurate standards for water potability control have been formulated for the U. S. Public Health Service and the Armed Forces[2]. A summary of these studies has been published in the November 1955 issue of the American Journal of Public Health[3]. The sanitary engineering profession and its duly appointed committees must take cognizance of this great forward stride in our efforts to secure ever tightening and more exact controls over water treatment and water quality.

What is one of the important objectives of scientists and engineers today? The development of means of securing greater sensitivity and precision of measurement! This involves the search for new techniques and the rigorous statistical analysis of results to prove or disprove their accuracy and precision. Sanitary scientists do not have to be accomplished statisticians, although such knowledge is of great help in laboratory research. The important point is that we must trust the mathematicians and place firm belief in their conclusions.

As one who has taught courses in statistics and used it as a research tool[4], the results of statisticians point to the unquestionable superiority of the membrane filter technique over any other practical method of measuring the bacteriological quality of potable waters on a precise basis.

The Old vs. the New

True, the M.P.N. analysis gives us a numerical answer, but what does this answer mean? The first part of the present U.S.P.H.S. standard, wherein not more than ten percent of all 10 ml. portions of sample examined per month for coliform organisms may be confirmed positives, constitutes an attempt to insure that the average monthly coliform density level will not exceed 2 or 3 coliforms per 100 ml. The second part of the U.S.P.H.S. standard, wherein less than five per cent of the standard samples (five 10 ml. tubes) can show three or more positive tubes per month, is aimed at the detection of coliform densities exceeding 10 per 100 ml.[2].

But, laboratory and statistical studies[2] show that in any one sample you can be *absolutely sure* that three out of five tubes will be confirmed positive only when the true number of organisms is 40 per 100 ml. If there are only 3 coliforms per 100 ml., and you are trying to detect these to assure maintenance of average standards in water quality, your tests will show that you will only have 3 or more tubes positive in ten percent of your samples! In other words, 90 per cent of the time that you may actually have this count you are being falsely assured by the negative results of individual samples. Similarly, if you are trying to detect momentary lapses of water quality, when coliform counts go above 10 per 100 ml., your results (3 or more positive) will only be correct 75 per cent of the time. The other 25 per cent of the time you will have missed the danger signal. On the other hand, using a 200 ml. sample and a true density of 4 or more per 100 ml. (the suggested U.S.P.H.S. standard)[2] the average membrane filter will detect the count of 8 or more per 200 ml. 99 per cent of the time. That is what a control test should do!

Furthermore, the proposed average monthly standard of one coliform organism per 100 ml. will have a real meaning to water works operators and represent a rigid control standard.

Precision the Major Advantage

Precision has thus been achieved far beyond that conceivable by any other practical method of coliform analysis. Realizing that *precision* is the most vital factor in water potability control, consideration can then be given to the advantages and disadvantages of the technique. Decisive advantages have already been pointed out by others.[1,2,5,6] These include: shorter processing time (18 hours vs. 48 to 72 hours); the possibility of testing any desired volume of sample; the ability to filter the sample in the field and start incubation in a small unit rather than transporting refrigerated samples over long distances; the greater reliability by securing actual bacterial numbers at the sampling site, rather than after growth or die-off during transit to the laboratory; the lowered cost of laboratory personnel, or greater productivity of existing personnel, make the membrane filter technique even more attractive . . . but, *precision* is still the *major advantage*.

Some writers[2,3,7] have reported on the disadvantages which exist with this technique. Turbidity may preclude the use of large samples. Correlation with average M.P.N. values may show lower numerical values. But statisticians can show that the M.P.N. result is naturally higher than the actual value[2], due to the peculiarities in bias of the M.P.N. test and the large sampling error involved in the use of fermentation tubes.

Lieber[8] has stated that there are manifold advantages of the membrane filter technique and has described some of the present shortcomings. However, his claim that large volumes of samples are required is not borne out by the extensive U.S.P.H.S. and National Academy of Science studies.[2,3,6,7] The standards suggested for the U.S.P.H.S. will employ 50 to 200 ml. samples.[2] His statement that costs of membrane filters are higher than broth and tubes is correct, but he has not taken into account the very real saving in techni-

cians' time and that greater acceptance and use will, without doubt, materially reduce production costs of membrane filters. Lieber correctly states that 24-hour presumptives can be used to warn sanitarians, but the tests must still be carried out for another 24 hours in order that they may be confirmed.

The research projects of Thomas and Woodward[3], Lieber[5], and others, have demonstrated the versatility of the membrane filter technique. True, it may require some further perfection in its application to the examination of tidal waters. And, further developments in media and methods of adaptation may also be required in order to adapt the technique to other applications of interest to sanitary engineers and public health officials.

Summary

It is the opinion of the author and many others that the advantages of the membrane filter for the control of potable water supplies, and for other purposes such as stream sanitation studies, far outweigh the disadvantages. Even in its present stage of development the membrane filter technique may be used to great advantage since *precision* of measurement is of paramount importance to workers in the field of sanitary science, and to water control authorities. The author is not suggesting dropping the fermentation tube technique as it will continue to be used by many analysts, but that the membrane filter technique be adopted as an equal control standard in our codes and in Standard Methods. Analysts and others may then choose to report results by either technique and will in all probability run parallel tests for awhile to observe correlation of results. Adoption of the membrane filter technique as an officially accepted standard procedure will be a genuine contribution on the part of sanitary science to the field of water quality control.

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Table For Determining Most Probable Numbers

Most Probable Numbers per 100 ml. of Sample. Tests by Fermentation Tube Method Using Three 10 ml. Tubes, Three 1 ml. Tubes and Three 0.1 ml. Tubes.

No. ml. 10.	Positive ml. 1.0	Tubes ml. 0.1	MPN	No. ml. 10.	Positive ml. 1.0	Tubes ml. 0.1	MPN	No. ml. 10.	Positive ml. 1.0	Tubes ml. 0.1	MPN	No. ml. 10.	Positive ml. 1.0	Tubes ml. 0.1	MPN
0	0	0		1	0	0	3.6	2	0	0	9.1	3	0	0	23
0	0	1	3.0	1	0	1	7.2	2	0	1	14.0	3	0	1	39
0	0	2	6.0	1	0	2	11.0	2	0	2	20.0	3	0	2	64
0	0	3	9.0	1	0	3	15.0	2	0	3	26.0	3	0	3	95
0	1	0	3.0	1	1	0	7.3	2	1	0	15.0	3	1	0	43
0	1	1	6.1	1	1	1	11.0	2	1	1	20.0	3	1	1	75
0	1	2	9.2	1	1	2	15.0	2	1	2	27.0	3	1	2	120
0	1	3	12.0	1	1	3	19.0	2	1	3	34.0	3	1	3	160
0	2	0	6.2	1	2	0	11.0	2	2	0	21.0	3	2	0	93
0	2	1	9.3	1	2	1	15.0	2	2	1	28.0	3	2	1	150
0	2	2	12.0	1	2	2	20.0	2	2	2	35.0	3	2	2	210
0	2	3	16.0	1	2	3	24.0	2	2	3	42.0	3	2	3	290
0	3	0	9.4	1	3	0	16.0	2	3	0	29.0	3	3	0	240
0	3	1	13.0	1	3	1	20.0	2	3	1	36.0	3	3	1	460
0	3	2	16.0	1	3	2	24.0	2	3	2	44.0	3	3	2	1100
0	3	3	19.0	1	3	3	29.0	2	3	3	53.0	3	3	3	

MAINTENANCE

MAINTENANCE comprises those operations which serve to keep equipment and processes functioning properly without interruption. Repairs, on the other hand, are those steps undertaken to restore broken or worn out equipment to operation. These two terms have frequently been used somewhat interchangeably. Some writers, therefore, have used the term "preventive maintenance" to avoid any possible confusion with simple repair operations.

In both water and sewage works, good plant control includes a program of preventive maintenance, for it has been said that "preventive maintenance is insurance against costly breakdowns."

Essentials of Good Maintenance

There are four basic elements in preventive maintenance. These are a thorough knowledge of the equipment or process, proper tools, adequate replacement or repair parts, and a planned program.

Knowledge of equipment can be gained from manuals of instruction furnished by the manufacturer with the equipment. Knowledge of processes and process operations can be gained from standard text books and magazines such as the Reference and Data Edition of WATER & SEWAGE WORKS.

Special tools may be required for particular apparatus, instruments, machines and equipment or particular maintenance operations. Regardless of the type of tool or its use, they should be adequate and properly sized for the function they are to perform. Furthermore, tools should be located in a specific place and returned there after each use. A good motto is: "A place for everything, and everything in its place" whether it be a delicate instrument, a Stillson wrench, a carpenter's level, or machinist's file.

Replacement or repair parts, commonly called spare parts should be stocked in numbers according to the number of machines to be serviced and the operating life of the part. Like tools, spare parts should be carefully and correctly labelled and kept in a specific location.

Planning a maintenance program is the job of the superintendent or manager of a water or sewage works.

Planned Maintenance Program

A preventive maintenance program should be set up for every piece of equipment, every structure, and every unit process in a water or sewage works system. This program should be aimed at accomplishing the overall desired objective of preventing costly breakdowns or loss of effectiveness and efficiency. Such a program will involve several factors.

1. Regular periodic lubrication, inspections, cleaning, and replacement of worn parts.
2. Systematic distribution of maintenance operations so that such operations on different equipment will not fall due at the same time.
3. Systematic scheduling of maintenance so that it will be done on a definite periodic basis. The use of a card record system avoids dependence on memory.—"A piece of paper never forgets."
4. A method for adjusting the inspection period to fit conditions as experience indicates.
5. Record cards to show date of maintenance, type of maintenance performed, condition of equipment, repair parts used, time spent on maintenance operation, and costs.

General Maintenance Operations

There are certain fundamental operations that can be applied as a part of any preventive maintenance program.

Standby equipment should be operated at regular intervals as should any equipment used infrequently. Inspection of all equipment should be the first step in every maintenance program. Cleaning operations are essential to maintaining anything in good operating condition. Lubrication at regular times with the proper lubricant is a must for equipment whose operation involves friction.

Equipment and facilities should be protected against damage from careless operation, and from careless or destructive passers by. Whenever necessary worn parts should be replaced and complete disassembly, cleaning and repairs may be desirable for some equipment at regular, if protracted, intervals. Corrosion may be prevented by applying protective coatings.

Specific Maintenance Problems

Among the many maintenance problems which arise there are some which stand out, either because they are unique or because their true maintenance character is not always recognized.

One of the most important maintenance operations is that of maintaining the carrying capacity of water mains and sewer lines. Corrosion and incrustation or slime formation in water lines often causes a serious loss in carrying capacity and pressure loss. Cleaning, or cleaning and lining, is the maintenance operation to be performed. Sewer lines may tend to become clogged with debris, stranded particles, settled grit and slime growths. Cleaning at regular intervals is required, but there is no protective lining that will help. In both water and sewer lines where slime growths tend to clog or reduce carrying capacity, the application of chlorine on a regular schedule is a preventive maintenance operation.

Cleaning of wells or performing operations that will assure continued full supply is termed maintenance. Filter washing is a maintenance operation, just as is the replacement of lost sand. Cleaning sludge beds in a sewage plant and replacement of sand are likewise maintenance operations. So too, is the washing of vacuum filter cloths (with or without acid) to increase the life of the cloth.

Maintenance Equipment and Services

To aid the superintendent or operator there are many pieces of special equipment which can be obtained from manufacturers. There are also maintenance services which can be obtained. Outstanding examples of special equipment include that for cleaning sewers.

Special maintenance services can be obtained to clean and reline water mains. Manufacturers of lubricants will gladly study any plant and develop both a list of the minmum lubricants required and a lubrication schedule. Paint and protective coating manufacturers offer free consultation and recommendations on preventing corrosion problems.

Many manufacturers of equipment offer a maintenance service program, whereby for a minimum fee and prorated expenses, a factory service man will make regular scheduled trips to the plant. Services rendered include disassembly, cleaning, lubrication, replacement of worn parts, indication of parts showing signs of wear, reassembly and adjustment. This service is particularly useful on complicated mechanisms, instruments, etc. in plants which cannot afford to have specialists on their maintenance staff.

Lubrication of Equipment For Water and Sewage Works

by EDW. A. TSCHIDA
Formerly, Supt., Water and Sewage, Dickinson, S. Dak.

SEVERAL THOUSAND YEARS AGO grease was used to lubricate the axles of Egyptian chariots. Samples of this grease, which was made with an animal oil, have been found in Egyptian excavations. During the Italian Renaissance, Leonardo da Vinci used grease mixtures for the lubrication of some of his remarkable inventions. Later, greases were used on the first crude steam engines and power driven machinery, which started the Industrial Age in the 18th Century.

Early American greases were made in open kettles suspended over an open fire. Crude petroleum and resin were stirred together and when the maker thought the mixture was hot enough, he stirred in a solution of milk of lime until it was thickened to suit him. These greases reflected the competency or incompetency of the maker and were far from being uniform in consistency, structure, or in fact characteristic.

Grease is a mixture of petroleum oil and soaps formed together into a plastic structure. It must be used to lubricate bearings where oil cannot be retained long enough to provide lubrication. Present-day greases are manufactured by scientifically controlled processes. Extreme accuracy of temperature control, exact weighing and measuring, and extensive mechanical developments make close control possible. All this is done to overcome friction, such as metal to metal contact.

What Friction Is

Friction is defined simply as resistance to motion. Suppose, for example, that two flat metallic surfaces rest one upon the other. It would appear that smoothly ground surfaces such as these would offer little or no resistance to the movement of one another. When these surfaces are greatly magnified, however, they are found to comprise innumerable microscopic irregularities, such as hills and valleys.

The interlocking of these irregularities produces a definite resistance to the motion of one surface over the other. The force necessary to start this movement is great. After the movement is once underway the force required for continued motion is smaller because inertia prevents the moving surface from dropping again into an interlocking position, and momentum carries the hills of the moving plate over the corresponding hills on the stationary plate. This is the condition that exists in a slide bearing operating without a lubricant.

The primary purpose of oil or grease lubrication in plain bearings is to introduce between moving metallic surfaces a fluid or plastic medium in the form of a lubricating film which separates the surfaces sufficiently to prevent metallic contact. This lubricating film substitutes fluid or plastic friction, which is the friction within the film itself, for harmful metallic friction.

Action of Lubricant

Lubrication of ball and roller bearings is a special case of grease lubrication. Their requirements are different, and they are considered separately. Ball and roller bearings offer less resistance to starting motion than do plain bearings, and are therefore known as anti-friction bearings. The lubrication of such bearings is entirely different from the lubrication of plain bearings, since the motion is theoretically of a rolling nature.

If the motion in this type of bearing were actually purely rolling in nature, the roughness of the contacting surfaces would offer practically no resistance to relative motion. In other words, if the theoretical "point contact" between balls and races could be maintained, no friction could be present. Similarly, if the theoretical "line contact" between rollers and raceways actually existed during operation, the resistance offered to the movement of the rollers would be negligible. In each instance, however, the slight deformation of the balls, rollers and raceways results in an appreciable area of surface contact and consequent slippage, and friction, between the moving parts. Additional friction is encountered between the balls or rollers, and their cages, consequently even in anti-friction bearings there is a certain amount of slippage, although the friction resulting from such is relatively small.

The dual purpose of lubrication in anti-friction bearings is to protect the highly polished and accurately ground surfaces from rusting and corrosion, and to minimize the friction resulting from the contact and slippage between moving parts. This is accomplished by the use of a lubricant that coats the balls, rollers and races with a protective and lubricating film.

The severe churning of the grease by the balls and rollers tend to introduce air into the lubricant. Where inferior products are used, this action swells the volume of the grease, impairs its behavior, and results in unsatisfactory lubrication. Therefore, suitable greases for anti-friction bearings should resist aeration to a maximum degree, and thus minimize loss of lubricant. A high quality grease will be found to possess a maximum resistance to oxidation, separation and aeration.

To insure a complete lubricating check, at the author's plants a chart is made up on a six-months basis showing each motor, gear reducer, pump, compressor, exhaust fan, etc., together with the type of oil and grease to be used. The chart also contains space for indicating the date and the person

making the lubrication change on each machine. It is well to have one man take care of this very important assignment, because otherwise it is too easy to "pass the buck" when something goes wrong. Extending this lubricating program to six months seems like a long time between oiling and greasing, but during this period everything is checked once a month and oftener for possible loss of oil or grease. Such equipment items as chemical feeders, motors, and moving parts, are constantly being watched for lack of lubrication.

A minimum of three kinds of oil and three kinds of grease is used at the sewage plant and a minimum of two kinds of oil and grease at the water plant.

When the new water plant began its operation in May 1952, a lubrication Engineer from one of the major oil companies went over the entire plant, and drew up a chart with lubrication recommendations. The speed of all the motors is 1725 rpm and a No. 3 grease was recommended for ball and roller bearings and a medium-grade oil for practically all of the plant's oil needs.

Many motors now in use have what the manufacturer calls a "life-time" bearing on small motors, and bearings designated as high as five years on large motors, such as the 125-hp motor used for pumping at the Dickinson plant. This motor has sealed bearings, and the manufacturer has a nameplate on it specifying a five-year limit for an almost continuous service. It is hard to imagine a machine running constantly for five years with no bearing wear. It makes the ordinary layman wonder just where he's been all these years.

Gear Lubrication

In the earliest machines that man built to do his work, gears formed an essential part. The teeth of these early gears were pegs, fashioned out of wood, and inserted in the rims of wooden wheels. They were crude affairs. The loads that were transmitted were necessarily light, and speeds were low. Lubrication was of little concern then, for when a tooth wore or broke its replacement was a simple matter. The first big forward step in gear design came when peg teeth were abandoned, and teeth shaped much like those in modern gears were developed.

With this advance, lubrication assumed an important role in reducing wear and prolonging the life of the gear. Here, too, metallurgy had developed, and correct profiling and proportioning of gear teeth came into its own. Thus, present-day gears, with their accurately cut teeth of correct profile and finely finished surfaces, are a far cry from the old wooden pegged gears of the past. Many types of gears are currently used, such as the spur gear, stepped gears, helical gears, hypoid, bevel, worm, and many other types of gears.

At the Dickinson sewage treatment plant, there is a double-throated worm, and worm gear, in the primary clarifier; also in the secondary clarifier and in the digester. These sets of gears power the gathering mechanism that collects the sludge to be drawn off by the sludge pump and put into the digester. All teeth contact to full depth and all the teeth of the worm are in working contact simultaneously, with the result that these gears have a considerable area of tooth contact. The worm gear is partially submerged in an oil reservoir, and supplies its lubrication in this manner during operation. A glass oil container is used as an oil feeder; the operator can see when a refill is needed.

During the spring cleanup, the gear mechanisms of the primary, secondary and digester are completely taken down in search of any faulty parts that may cause a shutdown at some time or another. After every part is cleaned and inspected and reassembled, the reservoirs are filled with oil, and the gears are completely oiled by hand so as to avoid any metal to metal wear at the beginning of the operation.

The sludge pumps are packed when needed, and this is not too often. The operator keeps a soluble oil mixed with water over the packing at all times for smoother operation. Many different kinds of oil have been tried for this particular operation until the oil exactly fitted to the particular use was found.

If at any time there is a breakdown and a motor or pump is taken down, it is well to take advantage of the situation. If time is available, here is a chance to clean the bearings or repack the pump, and perhaps re-align the motor and the pump shaft. Shaft alignment is of great importance. No matter how small or how large a pump or motor may be, there is always a chance that it may be out of line. Any mechanism out of alignment means wear and tear on the bearings.

In going over the manufacturer's recommendations on oiled ball bearings, and also on gears encased in a housing with a sightglass inserted, their instructions specifically recommend that during a shutdown period of any length of time, the sightglass should be filled to the very top and left that way until operation is resumed. Furthermore, the sightglass reads maximum and minimum; when operating, the oil level should be kept midway. The reason for recommending a full sightglass during a shutdown period is that when machines are left idle during a shutdown period with the oil left midway in the sightglass, the upper half of the bearing is left exposed to moisture, and the balls may become pitted. One little pit in one ballbearing may cause trouble in the future.

Small Motors

Lubrication of fractional horsepower motors should be mentioned. Most small motors have a small felt pad that feeds the oil to the motor shaft. After it has been run for some time this felt pad hardens and completely shuts off the oil feed to the shaft. In order to get the oil flowing freely again, a sharp instrument such as a dental tool is used to pierce the felt wick several times until the oil flows freely. About 99 per cent of all small motor trouble is caused by lack of lubrication and over-fusing.

In conclusion, it should be stressed that correct lubrication involves the application of the right lubricant, at the right place, in the right way. It follows that there should be a right lubricant for every type of machine made. The oil industry has found these correct oils and greases for every possible mechanism. It is a good feeling to know that lubrication specifications have been simplified by the oil industries to the extent that an expert can be called to give his recommendations, free of charge, whether it be for the simplest piece of mechanism or for the most intricate machine used in science.

Practical Methods for Attaining Proper Multiple V-Belt Tension

by FRANK H. RUMBLE

Allis-Chalmers Mfg. Co.

ANYONE at all familiar with the modern multiple V-belt drive is aware that a V-belt derives its grip from the wedging contact between the sides of the V-shaped belt and the sides of the V-shaped grooves of the sheaves. Because of this wedging contact, a V-belt requires less tension than a round or flat belt, which depends for its grip solely on frictional contact with the sheave surface.

This very fact sometimes causes trouble. Because of the effectiveness of their grip and the generally accepted fact that they do require less tension than other types, there is often a tendency to apply too little tension on V-belts. Experience shows that there are a great many more V-belt drives operating with insufficient tension than there are drives with too much tension. Drives with slack, sagging belts almost always need more tension. Proper adjustment will often remove the sag and cause the belts to operate more uniformly and efficiently.

Even though the V-belt drive requires less tension than other types, to operate correctly and assure longest life of both belts and sheaves a V-belt drive must have some tension on the belts. Otherwise, the belts will slip while in use, quickly wearing both belts and sheave grooves. Also, slack belts have a tendency to "whip," jerk, and not operate in unison.

The question is, naturally, what is the correct amount of tension for V-belts and what is a practical means of attaining it? Before attempting to answer these questions, it would be well to examine a few other facts.

Fig. 1—V-BELTS under proper tension feel springy and alive when slapped with the palm of the hand; slack belts feel dead

Initial Stretch

Like a pair of new shoes, V-belts when first installed need a "breaking-in" period. Over the period of their useful working life standard V-belts of rubber, cord and fabric will show a total stretch of approximately 4 per cent.

The stretch is effected gradually and may only become apparent after the belts have been under proper tension for a relatively long period. However, a small amount of this stretch occurs soon after belts have been installed and until they reach their working length. After this initial stretch is removed the belts resist further "give" and retain a large share of their elasticity.

It is possible, of course, to put so much tension on a V-belt drive that the belts themselves will be "tight as fiddle strings;" the belts will be unduly stretched and the bearings of motor and driven machine overloaded and damaged. However, this danger is not too great and is not frequently encountered unless excessive tension is applied deliberately and without reason.

All that is necessary on the average properly engineered drive is to apply enough tension to prevent slipping of the belts under full load. Slippage can readily be detected by use of a tachometer applied to driver and driven sheaves. If an excessive amount of tension is required to keep the belts from slipping, the engineering of the drive should be checked. Perhaps the drive should have larger diameter sheaves or more belts. Use of high-capacity type belts may offer a solution.

The phenomenon of belt sag is well known, but the facts in connection with it are often misinterpreted. Sometimes on a matched set of belts which has been in use, and frequently with newly installed matched belts,

some belts will sag more than others and appear to be considerably longer. Actually, this is not the case. In the modern method of matching V-belts the maximum difference in length between longest and shortest belts in the set is only 0.1 inch per 100 inches of belt length, or 0.1 per cent.

The amount of sag this may produce is deceiving. On a center distance of 100 inches on drives with both shafts parallel to the floor or base, a sag of 2 inches in a belt will appear drastic, yet it can be removed by only 0.054 inch of take-up on the motor base—less than 1/16 in.

Stretching the shorter belts in the set this small amount to bring them up equal with the others will not harm them. In fact, considerably more than this amount of stretch must be applied to all of the belts in the set.

Research has shown that V-belts operate best when under slight stretch, which is, of course, induced by putting them under tension. That is the reason the belts are made resilient and elastic—a necessary attribute of V-belts working in multiple. Belts under proper tension are operating under approximately 0.5 per cent stretch.

Measuring Proper Tension

It is impractical in the average shop or factory to actually measure the pounds of tension which are applied on a V-belt drive, such as can be done in the laboratory with special equipment. Exact measurement is not necessary, however; it is sufficient to have practical ways of approximating the correct tension.

The experienced operator can tell by observation and feel whether or not a set of V-belts is under proper tension. Unless the drive has an unusually long center distance, the belts under proper tension have little, if any, sag. A slack V-belt feels dead when thumped with the hand; a properly taut belt (Fig. 1) has an alive springiness.

There are other ways of judging whether or not a V-belt drive has the proper tension. One way is by use of a tachometer, as previously mentioned. After a set of belts has been installed, all the slack removed, and the drive started up, the rpm of the driver shaft can be checked with the rpm of the driven shaft according to speed ratio. Tension should be applied only to the point where no slippage is evident. The procedure should be repeated every few days until the belts are broken in and set properly.

Another method, favored by some operators, is that of depressing the belts as shown in Fig. 2. With the drive stopped, press down firmly on each individual belt. A belt which can be depressed an amount equal to its own thickness for each 48 inches of unsupported length is properly tensioned. This allows for the fact that the larger the cross-section, the greater the amount of tension required. Where 48 inches of unsupported length is not available, a proportional amount of pressure should be exerted.

Still another way of quickly attaining the approximate correct tension when installing a set of belts is to proceed as follows: After the belts are fitted in the grooves properly, move the motor away from the driven machine just to the point where belt sag is eliminated. Indicate the exact center distance by making a chalk or pencil mark on the motor base. Then make an additional take-up of ½ inch for each 100 inches of center distance (Fig. 3). Proportionate take-up should be made on longer or shorter center distances.

This will approximate about 0.5 per cent stretch and put the belts under the proper tension. They should be checked after the first few days use with the "hand thumping" or "depressing" method to be sure they have not loosened up. If so, more take-up will be required.

Fig. 2—ANOTHER METHOD of checking tension is to depress belts one at a time. A belt under proper tension can be depressed, with reasonable pressure, an amount equal to its own thickness for each 48 inches of unsupported length

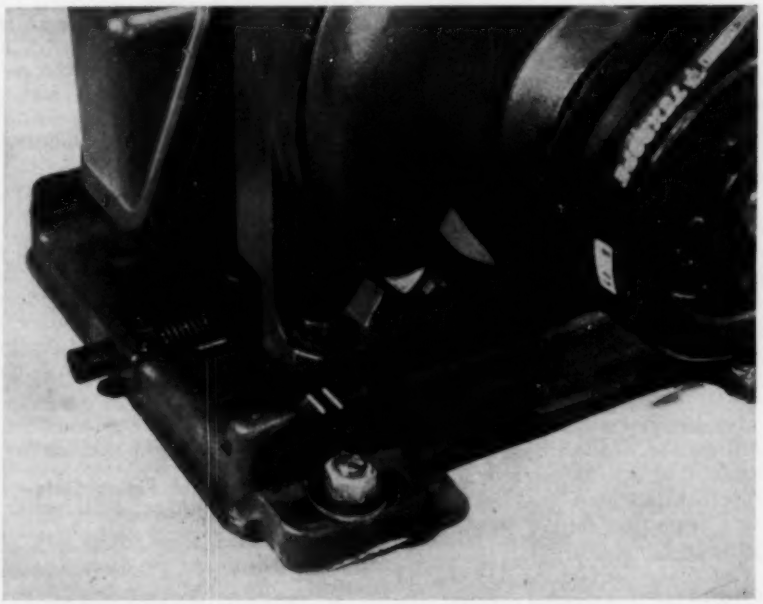


Fig. 3—PRACTICAL way to obtain 0.5 per cent stretch needed for proper tension is to fit belts in grooves properly, move motor away from driven machine until all slack and undue sag is removed, make chalk mark on base at end of movable plate, then make additional take-up in ratio of ½ inch for each 100 inches of center distance

Piping Color Codes*

COMM. REPORT ON PIPING COLOR CODES OF CALIF. SIWA.

THE SUBCOMMITTEE on Paints and Protective Coatings of the Federation is actively planning a painting manual adapted to the particular problems confronted at sewage and industrial waste treatment facilities. Interest in color codes for treatment plant piping has been expressed by several member associations and a number of operators and designers. Piping color codes evoke interest every time a new sewage treatment facility is designed and constructed, or when a plant superintendent plans a painting schedule for his installation.

In 1954, the California Sewage and Industrial Wastes Association appointed a committee to study piping color codes in an effort toward the development of a color scheme for consideration by the association membership. While this study was being undertaken the state of California adopted a standard pipe marking and safety color code for use at state-owned properties. This code is based on the standards for piping color codes in industry as developed by the American Standards Association, National Safety Council and American Society of Mechanical Engineers. The work of these professional groups has been comprehensive and provides an excellent basis upon which to prepare a specific color code for the sewage and industrial wastes field. Inclusion of a recommended color or other identification code is planned by the Federation's "Paint Manual" Subcommittee.

In further consideration of piping color codes excerpts from the color code for the state of California are presented for consideration.

Calif. Standard Pipe Marking and Safety Color Code

The need for a systematic and uniform method of identifying materials contained in pipes throughout all state properties has been apparent for so many years that further justification should be unnecessary.

One reason supporting this need is to have maintenance and construction personnel readily familiar with piping even though transferring from one institution or property to another. This in itself would conserve incalculable amounts of time, and therefore money, for the state. Another reason supporting this need is to permit quick familiarization by outside personnel in the event of major disaster or calamity such as fire, flood, earthquake, bombing or other unforeseen event.

At the present time, if it became necessary for Civil Defense, National Guard, Army, Navy or other agency to assume the operation of any state properties on an emergency basis, operating personnel would be severely handicapped in attempting to orient themselves. Much unnecessary and perhaps dangerous confusion would result due to lack of piping identification.

This system was set up with the thought that it should be inexpensive to install, require a minimum of effort to maintain, be simple to become familiar with and be all-inclusive in scope, as well as most effective.

Table I presents the basic features of the piping system identification method, including the classification letters, class description, color and special uses for which each class is designated. This method is to be used as the standard safety color code for the entire scope of purposes for which pipe markings will be necessary. Specific material classifications and recommended legend, color and banding are given in Table II as they may be applicable to sewage and industrial waste treatment facilities.

Material Classification

This column gives the classification letter for the material conveyed in the pipe as approved by the American Society of Mechanical Engineers, American Standards Association and National Safety Council and is not to appear on the piping.

TABLE I

Basic Features of Piping System Identification

Classification	Description	Color	Special Uses
F	Fire protective	Red	Danger
D	Caution	Yellow	Caution
D	Alert	Orange	Electrical
S	Safety	Green	Safety
P	Protective	Blue	Protection
—	—	Brown	Waste lines

Legend

This column shows the printed legend, as it shall appear on the pipe in conjunction with the direction of flow arrow pointing in the direction of flow. The legend is the mandatory portion of the system.

This printed legend with the direction of flow arrow must appear as specified to conform or qualify as a standard pipe marking code.

Banding

Banding shall be used when it is deemed necessary or desirable to include banding of piping in classification colors.

One-inch colored banding shall be applied on the piping 1 in. from the immediate *left* of or preceding the stenciled legend and direction of flow arrow. The banding shall be as follows:

Primary mains	Three 1-in. bands
Intermediate or secondary mains	Two 1-in. bands
Branch mains or equipment service	One 1-in. band

Color

This column identifies the classification color as approved by the ASME, ASA, and NSC for each material as listed. The identifying colors, red, yellow, orange, green, blue and brown, shall apply for whatever materials are used; paints, cellulose tapes, fibered tapes, gummed paper or other.

The classification color shall be used when painting identification bands or the entire pipe should it be deemed desirable to use this latter type of system. However, when the entire pipe is painted a band of ample width to accommodate the legend portion of the system shall be provided in white or pastel color in ample contrast to any of the classification colors as to be readily distinguishable.

Additional Banding

This column gives the additional banding to be used in the event supplemental safety or precautionary marking proves necessary or desirable. It should be noted that the band size called for is ½ in. in width. These bands shall be placed ½ in. apart where more than one band occurs,

*Reprinted from *Sew. & Ind. Wastes*, Vol. 28, No. 6, p. 813 (1956).

and commencing 1 in. to the immediate *right* of or after the printed legend and direction of flow arrow. This additional banding is designed to indicate such things as the danger or safety of the material carried as pertains to its degree of explosiveness, inflammability or danger to life and limb. For example: three ½-in. red bands would indicate an explosive material, two ½-in. red bands an inflammable material, one green band a very safe material, etc.

On small pipes with outside diameter of 2 in. and less, the height of letters used shall be equal to approximately one-half the outside diameter of the pipe, *i.e.*, ½ in. on 1-in. pipe, and 1 in. on 2-in. pipe. On larger piping, the same rule shall prevail up to the use of a maximum size letter of 3 in. in height. The printed legend shall appear at all valve locations, wherever and whenever a pipe passes through an obstruction, both at the point of entry into and/or egress from or within a reasonable and convenient distance therefrom (a reasonable distance being within 4 ft.). Wherever two or more pipes run parallel, the printed legend and other markings shall be applied in the same relative location so as to be in either vertical or horizontal linearity, whichever the case may be. The printed legend, with direction of flow arrow, shall appear as many times as is necessary along the pipe to be readily conspicuous at all times from any reasonable point of view.

All pipes shall be marked at both ends if the total length exceeds 10 ft. No piping shall run more than 30 ft. between markings, except in cases where the pipe is so located as to preclude this necessity. This would be if the pipe were confined to a tunnel, run overhead for long distances, or buried, in which case common sense and good judgment of needs shall be considered.

Instructions and Suggested Methods of Application

The use of paper stencils for the printed legend should present little or no problem. In case of smaller installations, arrangements can be made with a place of business having a shipping department to cut a nominal amount of paper stencils for little or no charge. The stencils should be attached to the pipe and made to lay closely with the use of masking tape. Stencils thus attached can be sprayed with paint and, on removal, should result in a sharp, clean edged printed legend.

Paints for lettering, as recommended, are available in pressurized cans. The use of paint materials packaged in this manner is recommended, as there will be no labor required for mixing and preparation of paints or usual messy clean-up work on completion. Also, these paints can be on hand for additional marking work as may be necessary at any later date.

Tapes, in colors corresponding to the standard colors, are available in widths as specified for the color banding. These colored tapes are manufactured expressly for the purpose of pipe marking, and the fiber types are quite durable.

By following the foregoing recommendations and specifications, no special skills are required to apply this pipe marking system. Any man in the maintenance staff possessing the qualities of neatness and normal mechanical ability should be capable of pipe marking without assistance, except perhaps a man not familiar with the piping who therefore would need to have the various pipes named as to contents by someone on the mechanical maintenance staff.

Other Uses

The safety color code portion of this system is intended for use throughout any installation. The uses to which this color code can be put are numerous. It could be used in various shops to mark off locations that are safe, hazardous, or dangerous; to paint electrical switch boxes (orange); "No Smoking" signs (white lettering on red background); first aid equipment (green); protective equipment (blue); etc. Containers for various liquids such as gasoline cans (red); water (green); etc., can be marked in any and all areas of institutions to indicate danger, caution, alert, safety, and the protective status of the container or item.

TABLE 2
Standard Pipe Marking and Safety Color Code

Material Classification	Printed Legend with Direction of Flow Arrow	Color Code	Additional Safety Banding
S	Domestic water[1]	Green	3-Green
S	Industrial water[1]	Green	1-Green
F	Fire protective water	Red	1-Green
D	Hot water supply or return (domestic)	Yellow	1-Green
D	Hot water supply or return (heating)	Yellow	1-Green
S	Distilled water	Green	1-Green
D	Boiler feed water or blow-off water	Yellow	1-Green and 1-Yellow
D	Pressure steam	Yellow	2-Red
D	Acetylene, butane, exhaust or flue gas	Yellow	3-Red
D	Gasoline	Yellow	3-Red
D	Manufactured, natural, propane or process gas	Yellow	3-Red
D	Fuel oil or diesel oil	Yellow	2-Red
D	Chlorine	Yellow	2-Red
D	Oxygen	Yellow	2-Red
S	Compressed air	Green	1-Yellow
S	Vacuum air	Green	—
—	Sanitary sewer, raw sewage influent	Brown	—
D	Danger, electrical (exact voltage)	Orange	3-Red

[1] "P" or "NP" after legend indicates whether potable or non-potable water.

Upper Mississippi River—Great Lakes Board

The Upper Mississippi River—Great Lakes Board of Engineers, representing 10 states, has suggested the following standard color schemes for sewage treatment plants:

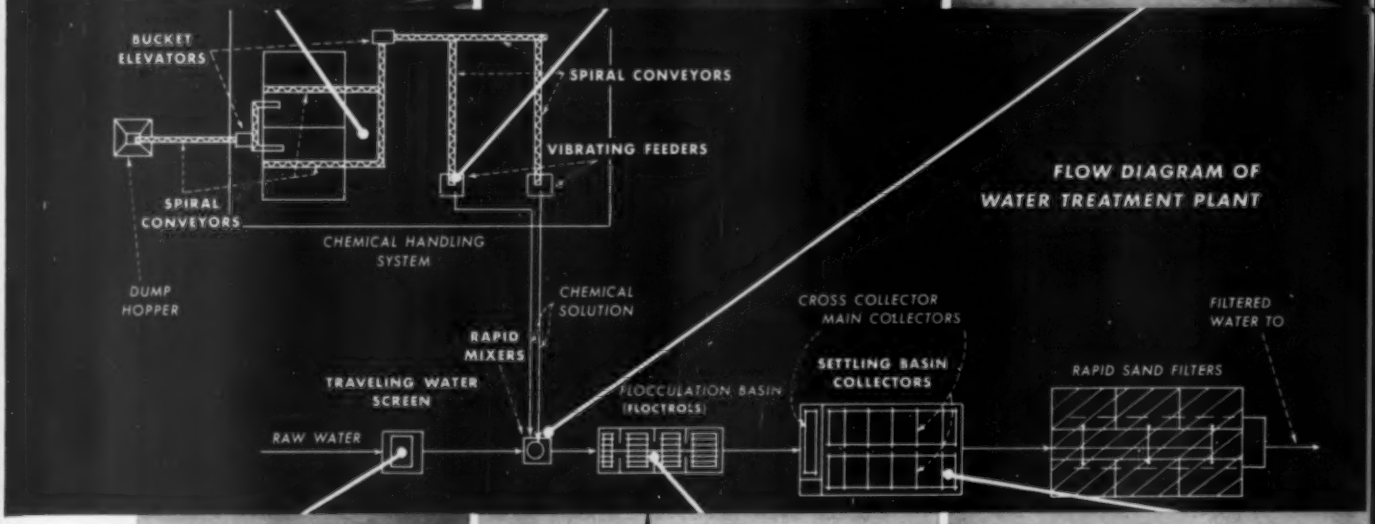
Piping	Color
Sludge	Brown
Gas	Red
Potable Water	Blue
Chlorine	Yellow
Sewage	Gray
Compressed Air	Green

This is a relatively easy list of colors to remember and the choice of colors appears logical. There is a natural association in the minds of most operating personnel between the color noted and the material conveyed. The system avoids the use of a band or legend, thereby making it well suited for small plants or uncomplicated pipe systems. Directional flow arrows, however, are desirable.

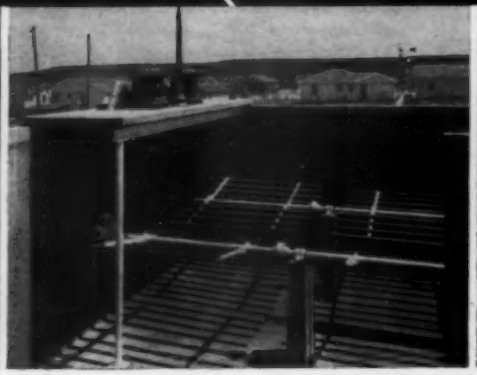
Bucket Elevators fill these storage bins. Spiral conveyors carry chemicals away.

Eight WAYTROLS here in this waterworks automatically proportion chemicals for mixing.

Mixers insure proper blending of coagulant solutions, assuring most economical use of chemicals.



Traveling Water Screens remove all floating debris and suspended matter from plant influent.



FLOCTROL tanks give complete flocculation in shortest possible time, with minimum chemical usage.

Sludge Collectors for settling basins are designed for quiescent flow to speed sedimentation.

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JEFFREY's sixty-five years' experience with material-handling equipment qualifies the JEFFREY Sanitary Engineering Division to offer complete technical assistance on water treatment plant equipment and design. Catalog 833-A describes this equipment. The Jeffrey Manufacturing Company, Columbus 16, Ohio.

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IV. WATER WORKS OPERATIONS

FROM THE PROCUREMENT of the original supply to the ultimate delivery of water to the consumer, the operation of a water works system involves many sciences both pure and applied, including physics, chemistry, hydraulics, engineering of all kinds, bacteriology, liminology, psychology, economics and statistics.

The following section is devoted to the general subject of water works operations and the various phases thereof. Space does not permit the inclusion in one issue of all the basic articles on this subject. Other good articles of reference nature will be found in the previous Reference and Data Numbers.

The following outline shows the broad scope of water works operations.

OUTLINE OF WATER WORKS OPERATIONS

I. Source of Supply
- A. Surface Water
  - 1. Streams and Rivers
  - 2. Ponds and Lakes
  - 3. Impounding Reservoirs
    - a. Yield
    - b. Site Selection
    - c. Site Preparation
    - d. Required Capacity
    - e. Losses
    - f. Siltation
    - g. Effects of Storage
    - h. Watershed sanitation
  - 4. Dams
    - a. Purpose
    - b. Types
    - c. Sites
    - d. Earth
    - e. Spillway
  - 5. Floods
    - a. Control Provisions
    - b. Flood Routing
- B. Ground Water
  - 1. Occurence
    - a. Percolation
    - b. Water-bearing formations
    - c. Underground flow
  - 2. Quality
    - a. Solvent action of water
    - b. Pollution
    - c. Characteristics
  - 3. Types of Underground Supplies
    - a. Springs
    - b. Infiltration galleries
    - c. Wells
      - (1) Types
        - (a) Shallow
        - (b) Deep
        - (c) Ranney
      - (2) Location
        - (a) Divination
        - (b) Geological
        - (c) Sanitary considerations
        - (d) Spacing
      - (3) Construction
        - (a) Shallow
        - (b) Deep
        - (c) Gravel packed
        - (c) Ranney
      - (4) Capacity and yield
      - (5) Development
      - (6) Pollution
      - (7) Operation
      - (8) Maintenance
- C. Characteristics
  - 1. Physical
  - 2. Chemical

II. Treatment
- A. Coagulation
  - 1. Theory and need for
  - 2. Mechanism
  - 3. Factors in coagulation
    - a. Subject to control
    - b. Other
  - 4. Coagulation Aids
    - a. Artificial nuclei
    - b. Solids contact
    - c. Activated Silica
  - 5. Control
  - 6. Application
- B. Mixing
  - 1. Basins
  - 2. Mechanical
  - 3. Flocculation
- C. Sedimentation
  - 1. Types of basins
    - a. Rectangular
    - b. Circular
  - 2. Detention time
  - 3. Flow-through time
  - 4. Sludge removal
- D. Aeration
  - 1. Types of aerators
    - a. Waterfall
    - b. Injector
    - c. Other
  - 2. Application
    - a. CO_2 removal
    - b. Odor removal
    - c. Oxygenate water
    - d. Iron and manganese removal
- E. Filtration
  - 1. Principles
  - 2. Types of filters
    - a. Slow sand
    - b. Rapid sand
    - c. Diatomite
    - d. Pressure
    - e. Miscellaneous
  - 3. Hydraulics
  - 4. Results
- F. Taste and Odor Removal
  - 1. Causes of odors
    - a. Algae
    - b. Protozoa
    - c. Bacteria
    - d. Chemicals
      - (1) Natural
      - (2) Industrial Wastes
    - e. Enhancement
  - 2. Determination of T. & O.
    - a. Methods
    - b. Techniques
  - 3. Treatment
    - a. Preventive
      - (1) Algae control
      - (2) Weed control
      - (3) Pollution control
    - b. Corrective
      - (1) Aeration
      - (2) Coagulation and Sedimentation
      - (3) Chemical oxidation
      - (4) Adsorption on activated carbon
        - (a) Points of application
        - (b) Dosage
        - (c) Handling and feeding
- G. Disinfection
  - 1. Need for
  - 2. Methods
    - a. Physical agents
    - b. Chemical agents
  - 3. Chlorination
    - a. Agents
    - b. Methods of feeding
    - c. Dosage
    - d. Control
  - 4. Ozonation
- H. Softening
  - 1. Need for
  - 2. Methods
    - a. Lime
    - b. Lime-soda
    - c. Ion exchange
  - 3. Treatment practices
  - 4. Control
  - 5. Results
- I. Miscellaneous Treatment
  - 1. Iron removal
  - 2. Manganese removal
  - 3. Fluoridation

III. Distribution
- A. Elements
  - 1. Distributing reservoirs
  - 2. Conduits and transmission mains
  - 3. Pipe lines and net works
  - 4. Valves
  - 5. Hydrants
  - 6. Services
  - 7. Meters
- B. Operation
  - 1. Service installation
  - 2. Field studies
  - 3. Loss of Carrying Capacity
  - 4. Maintenance
  - 5. Meter testing
  - 6. Other problems

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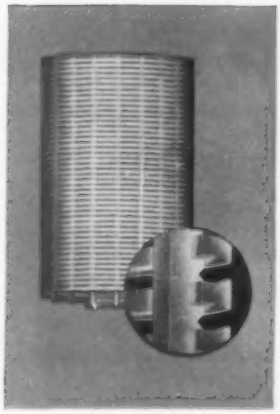

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WORLD'S LEADING NAME IN WELL STRAINERS

Well Rehabilitation by Chlorination

Chlorine applications specifically to eliminate clogging growths of iron bacteria

by A. E. GRIFFIN

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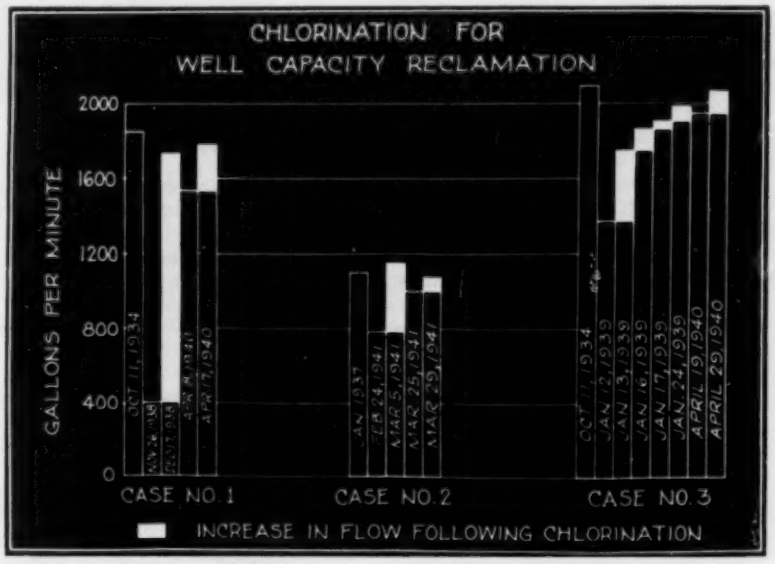
CHLORINE treatment to increase the yield of wells, sometimes called well rejuvenation, seems to be standard practice in that broad area of the United States lying between Lakes Michigan and Superior southward to the Gulf of Mexico. That the method is so widely used in this area is because iron bacteria, the bacteria which clog well screens so effectively, and which yield to chlorine treatment so easily, are especially abundant in the underground water throughout this territory. In fact, the area immediately adjacent to Green Bay, Wisconsin has earned the reputation of harboring the most lush growth of iron bacteria of any place in the United States and perhaps of any place in the world.

Chlorine treatment was born of necessity and has prospered by its practicality. The treatment is specialized and is effective when used specifically for the elimination of the bacterial growths that clog well strainers, the areas immediately adjacent to the strainers, the pump bowls and the piping leading to the surface. Where well capacities have declined considerably because of these growths, and where there has been a negligible change in the ground water level, chlorine treatment has increased capacities sometimes to their original figure.

Selecting the Point of Application

For such treatment the point of application should preferably be at the bottom of the well. When applied at this point, the chlorine comes in immediate contact with the sand and gravel surrounding the screen, the screen, the pump, and by diffusion with the piping above the pump. The usual routine is to apply the chlorine and then allow the well to "soak" from 12 to 24 hours—assisted, perhaps, with occasional "bumping" or "surging" to make sure that the chlorine is carried up into the pump bowls and the piping carrying the water to the surface. This practice also tends to force the chlorinated water into the sand and gravel surrounding the screen. Of course, the well must be flushed before replacing in service.



THREE CASE HISTORIES—The effect of chlorination on recalamation of well capacity.

Where it is impossible or impractical to apply the chlorine at the bottom of the well it may be applied to the pump discharge. When applied at this point the main discharge line should be closed and a by-pass of smaller diameter should be installed. Chlorine is applied to this by-pass water with which the well is back-flushed after the well has "soaked" in heavily chlorinated water, containing 50 ppm to 100 ppm residual chlorine.

Rate of Chlorine Feed Required

The rate of chlorine feed depends, of course, on the rate of water feed used in back-flushing, and the amount of chlorine used depends upon the quantity of water needed to displace the water in the suction pipe and in the area immediately adjacent to the screens. Care must be taken to prevent overdosing with chlorine to the point where the pH value of the water will be reduced below 4.0. If the pH is allowed to drop much below 4.0 the screens may be damaged due to the action of hydrochloric acid.

Should the decrease in yield be due to the presence of excessive amounts of dissolved salts, or to iron hydroxide or carbonate, other cleaning methods than chlorination should be used. Furthermore, chlorine treatment should not be used where the drawdown is so great as to allow the entrance of air. In such instances, the use of chlorine may "worsen" instead diminish the difficulty. The severity of the problem determines the frequency of treatment.

Case Histories of Well Cleaning

In certain instances where "biofouling" has reached undue proportions, repeated flushing with chlorine may be required at the start, as indicated by Case No. 3, Fig. 1. However, once the original clean-up has been accomplished, subsequent treatments usually are mild in character. Where pumping is intermittent, and the chlorine is applied in the well, excellent control can be obtained by so arranging the chlorinator equipment that a measured amount of chlorine will flow back into the well between pumpings. Where pumping is continuous, it usually is necessary to back-flush on a regular schedule.

In Fig. 1 are presented operating

data on three typical wells whose capacities had dropped to the danger point. In Case No. 1 accumulations around the screen and in the sand had reached such proportions within four years that the well was almost useless. Following alternate treatment with chlorine and proper flushing, the well capacity was increased to 1740 gpm. On April 8th, its capacity was down to 1540 gpm., which was quickly brought up to 1780 gpm. by chlorine treatment on April 19th, 1940. These figures indicate that the growth of the mineral bacteria in this case was relatively slow, but could be eliminated quickly and at slight cost.

Case No. 2, Fig. 1, is somewhat different. This is a well of relatively low yield, falling off in capacity by about 30 per cent over a four-year period. Chlorination brought it back to a yield above the original. However, within a three week period its capacity was again on the downgrade, a circumstance which was remedied by chlorination. It is evident from these data that this well should receive very frequent applications of chlorine.

Case No. 3, Fig. 1, is quite similar to Case No. 1, wherein a large drop in well capacity was noted during the first few years of service. Due either to timidity in chlorination or to especially resistant organisms, repeated surgings with chlorine were required before the desired capacity was restored. Once this capacity was obtained, however, the loss was very slight during the following year; mild chlorination again restored its yield almost to that obtained when the well was first placed in service.

Organisms Involved in Well Fouling

Insofar as can be determined, the bacteriological accumulations on the well screens and surrounding strata are similar in character to the "biofouling" material found in the water distribution system.

The organisms responsible for these organic deposits belong to a group not ordinarily isolated in a sanitary water analysis. This is due to the facts that many of them will not grow on the ordinary culture media employed; that some of them are very difficult to cultivate on any media; and that they seldom are dispersed in the water in appreciable concentrations. Thus, unless their numbers grow to the point where difficulties of one sort or another arise, or unless the coating on the interior of the mains, standpipes, etc., is carefully examined, their presence may go undetected for years.

These water slimes, or organic deposits, usually consist of mucilaginous mixtures of capsulated bacteria, various forms of iron, aluminum, and manganese bacteria, together with higher forms of micro-organisms which may abound in the water itself.

Chlorination Can Reduce Pipe Line Friction

A report on experience using intermittent chlorine treatment

by JOHN A. FULKMAN

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THIS is a summary report of tests conducted to determine friction loss of head in two new water supply pipe lines, before and after chlorine treatment of the water. One of these pipe lines carries raw water from the DesPlaines River, and the other line carries water from the Kankakee River. Tests were made in March, 1953, before chlorine treatment, and in December, 1953, after chlorine treatment.

Chlorination of the water was started in June 1953 and has been continuous to the present time. Intermittent chlorination has been found successful. The rate of chlorine application is approximately 50 pounds per million gallons for 7 minutes during each 2 hours.

The water supply pipe lines are welded steel, 42-in. inside diameter, and have a bituminastic lining. The pipe lines have been in service for more than ten years.

The DesPlaines River carries treated sewage effluent and drainage from the Chicago area. The pipe line supplying water from this river is 11,817 feet long, and includes several bends. The results of tests before and after chlorine treatment are reported in Table 1.

The second pipe line carries raw water from the Kankakee River. This river flows through a rather densely-populated area in Northern Indiana and Illinois, and is used for the public water supply of the City of Kankakee, Illinois. The pipe line on which tests were made is 20,278 feet long. The pipe line supplies water for use at a defense plant, and therefore the identity is not given. The results of tests before and after chlorine treatment of the second pipe line are given in Table 2.

TABLE 1

Data on Pipe Lines Carrying DesPlaines River Water

Flow Gallons Per Minute	Loss of Head in Feet	Loss of Head Feet Per 1000 Feet of Pipeline	Approx. "C" Value (Williams & Hazen)
(Determinations in March, 1953, Before Chlorine Treatment)			
25900	53	4.48	92
13200	15	1.27	93
20800	37	3.13	92
(Determinations in December, 1953, After Chlorine Treatment)			
27000	30	2.54	130
15000	10	0.85	130
20700	18	1.52	130

TABLE 2

Data on Pipe Lines Carrying Kankakee River Water

Flow Gallons Per Minute	Loss of Head in Feet	Loss of Head Feet per 1000 Feet of Pipeline	Approx. "C" Value (Williams & Hazen)
(Determinations in March, 1953, Before Chlorine Treatment)			
14700	23	1.14	111
20300	40	1.97	111
24400	59	2.91	111
(Determinations in December, 1953, After Chlorine Treatment)			
18000	27	1.33	125
20000	33	1.62	125
24400	47	2.30	125

Increasing Well Capacity with Calgon

by LOUIS R. CAPLAN

District Representative, Parr Engineering Co., Washington, D. C.

A CONSISTENT and economical supply of water is an essential to every municipality and industrial plant. Frequently new sources of supply must be developed to meet needs of expansion or relocation—and always realization of the full potential of the water supply is desired.

Water sources are varied but generally fall into the two classifications of surface supplies and ground or well water supplies. Here we wish to consider a means (1) of helping new wells to produce at the maximum output consistent with practical limitations of draw down and pump capacity, and (2) of rehabilitating old wells which have dropped off in productive capacity.

Depletion or limitation of the output of a well may be the result of mechanical failures—in which case appropriate repairs are, of course, indicated. More frequently, however, the loss or lack of capacity is caused by plugging of the screens or the water bearing strata around the well with minerals deposited from the water, with natural clays, silt, iron oxide or calcium carbonate, or by iron bacteria and slime forming organisms. To solve this problem a procedure has been developed for cleaning wells using the glassy phosphate, Calgon.

Properties of Calgon

Calgon is a phosphate glass produced by a thermal process from soda ash and food-grade phosphoric acid; it contains not less than 67 per cent P_2O_5. Calgon is essentially neutral having a pH of 6.7 to 7.0 in 1 per cent solution. It is generally used in water works practice in a form having the appearance of small flat platelets similar to broken window glass.

Calgon has many unusual properties which have led to its widespread use in water treatment. Probably the property most familiar to water works engineers and operators is the adsorption of the glassy phosphate on the surfaces of metals and their oxides and salts. This is the basis for the uses of Calgon known as "Threshold Treatment," which include prevention of the precipitation of calcium carbonate or lime scale[1] and the formation of thin phosphate films on metal surfaces to control corrosion.[2] This property, combined with the complexing and dispersion abilities of Calgon, makes it possible to prevent the precipitation of dissolved iron in iron-bearing water supplies.[3]

Now, in making available an effective agent for cleaning wells, another striking characteristic of Calgon is applied in the water works field. One of the fundamental properties of the glassy phosphate is its pronounced ability to disperse finely divided metal oxides and salts, including calcium carbonate, clays and similar materials.[4] This action of Calgon is easily demonstrated.

Dispersal Action Demonstrated

In Fig. 1 it will be noted that the 55 per cent calcium carbonate slurry in the left beaker shows no flow when inverted. The beaker on the right, however, shows good flow from a 70 per cent calcium carbonate slurry which is treated with Calgon. This fluidity is caused by the dispersing action of the glassy phosphate adsorbed on the calcium carbonate particles.

Fig. 2 gives a striking picture of the effect of Calgon on iron oxide. Prior to taking the picture, identical amounts of iron oxide sludge were placed in three graduated cylinders and made up to volume with water. To the second graduate was added 500 ppm of Calgon and to the third, 1000 ppm. No Calgon was added to the first cylinder. After thorough shaking, the cylinders were allowed to stand about two hours before the picture was taken. In fact, the iron oxide in the untreated sample settled to the bottom in only a few minutes time whereas that in the Calgon-treated cylinders remained in suspension after 24 hours.

The dispersing action of Calgon has been applied to the deflocculation of clays and pigments in the paper, ceramic, and paint industries; selective flotation of ores; and in oil field well drilling muds.

Well Cleaning by Dispersal

But what has this to do with well cleaning? Let us consider the substances which cause the plugging and, therefore, restrict the capacity of wells. These include not only substances deposited from the water such as calcium carbonate and iron oxide but also clay, silt, and various inorganic minerals present in the strata. Typical constituents of suspended matter removed by well cleaning operations are shown in Table 1.

Reference to this table indicates substances of the type that are dispersed by Calgon.[5] It is notable that although some of these minerals, such as calcium carbonate and iron oxide or carbonate, could be dissolved by acid most of them would not have been affected by acid treatment. This confirms carefully observed field results indicating that the glassy phosphate is one of the most effective agents yet developed for restoring capacity of those wells in which screens or the aquifier around the well have been plugged by mineral deposits. In most cases the glassy phosphate treatment produces results superior to those obtained with inhibited acid.

Calgon Treatment Method

The procedure for cleaning wells with Calgon is a relatively simple one, and has been well standardized for application to most types of wells. A

Table 1

SUSPENDED MATTER FLUSHED FROM WELLS

Well Location	Major Constituents	Minor Constituents
Chemical plant (southern Illinois)		
Well No. 1	Amorphous silica	Calcium phosphate, hydrated ferric oxide, calcium carbonate.
Well No. 2	Hydrated ferric oxide	Calcium carbonate, calcium phosphate.
Well No. 3	Iron carbonate, calcium phosphate	Feldspar, calcium carbonate, calcium sulfate.
Well No. 4	Calcium carbonate	Ferric oxide, feldspar, quartz, calcium phosphate.
Well No. 5	Quartz	Ferric oxide, silica, calcium carbonate and phosphate.
Industrial plant (near St. Louis)		
Well No. 1	Quartz	Particles of clay, ferric oxide (sulfide odor)
Well No. 2	Quartz, amorphous silica	Hematite.
Well No. 3	Hematite, hydrated iron oxide	Magnetite (sulfide odor); many bacteria present, including sulfate-reducing type.
Municipality (Illinois)		
1st flushing	Quartz	Magnesium silicate, calcium carbonate, ferric oxide.
2nd flushing	Magnesium silicate, calcium carbonate	Ferric oxide, quartz.

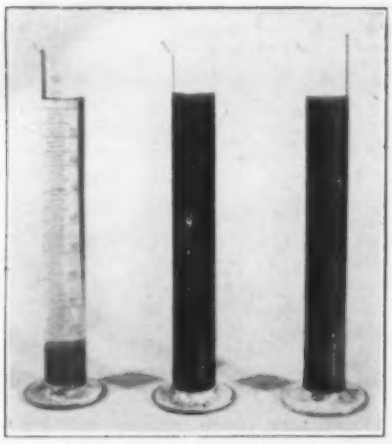

Fig. 2—EFFECT on iron oxide sludge. Untreated sludge in water (left) settle rapidly. Sludge treated with 500 ppm of Calgon (center) or with 1000 ppm (right) remains dispersed for 24 hours.

It is not unusual for wells cleaned with Calgon to develop capacities higher than when new. At one Midwestern municipality, the original specific capacity of a new well was 20 gpm per foot of draw down but had dropped sharply after only a year of operation. Acid cleaning restored the original capacity. Although doubtful of further improvement the municipal authorities consented to try cleaning with glassy phosphate. One charge of 200 pounds of Calgon plus hypochlorite was used, and surging was carried out for only 24 hours. Specific capacity increased to 40 gpm per foot of draw down—a 100 per cent increase over that when the well was new. Material cost for Calgon cleaning was only $35.00, compared with the cost of the first cleaning using 1700 gallons of acid.

A Maryland plant depends for a portion of its supply on a well water high in dissolved iron content, concentrations varying between 20 and 25 ppm. The use of air lift pumping of this well quite expectedly produces rapid plugging with iron oxide deposits and reduction of output. Periodic mechanical cleaning at about twelve month intervals had been resorted to as a means of restoring capacity but had never produced a delivery higher than 90 gpm, whereas original rated capacity of the well was 135 gpm.

Recently, after a 14 month period of operation following the last mechanical cleaning had resulted in reduction of capacity to 4 gpm, it was decided to chemically clean the well using Calgon and hypochlorite. The first chemical charge and cleaning procedure increased capacity to only 20 gpm. However, a total of four charges were used and checks after each period indicated successive improvement to 70 gpm after the second charge, 110 gpm after the third, and finally after the fourth charge an output of 153 gpm was obtained. This cleaning procedure not only produced better results than mechanical cleaning and an output exceeding initial rated capacity of 13 per cent, but proved more economical in outage time, and in costs of labor and material.

Reduced Pumping Costs

Not insignificant are the savings in pumping costs resulting from cleaning wells with glassy phosphate. A well in New Mexico had a draw down of 290 feet when pumped at 250 gpm. Calgon cleaning increased the specific capacity by approximately 75 per cent in one treatment. The reduction in pumping head amounted to a saving of about 135 kilowatt hours per day, which at two cents per kilowatt hours adds up to a saving of about $1000.00 per year.

At an industrial plant operating eleven wells, some with concrete casings, the glassy phosphate cleaning procedure was applied by one plant engineer after trying acid to check rapid loss of well capacity. The acid procedure was found to be expensive and cumbersome, and some concrete wells were damaged. On one of these wells, having a specific capacity of 14 gpm per foot of draw down, acid cleaning brought the output up to 400 gpm. Subsequent cleaning with Calgon shot the output up to 1200 gpm, which corresponded to a specific capacity of 30 gpm per foot of draw down. The rehabilitation program at this plant increased total capacity of the eleven wells from 6446 gpm to 8657 gpm—a 34 per cent gain—while reducing draw down by 21 per cent. The corresponding reduction of 9.2 per cent in total pumping head accomplished appreciable savings in pumping costs.

Calgon Method and Shallow Wells

We have thus far reported only on the cleaning of deep wells. It is noteworthy that with slight modifications, this cleaning procedure has been applied successfully to large diameter relatively shallow wells. In New England, large diameter wells have been cleaned by sealing and by providing necessary agitation using compressed air.

On other large diameter wells it has been found necessary to sink a series of well points around the periphery of the well, and thus to recirculate the strong solution of Calgon through the strata. Using this method it has been possible to clean a porous concrete well 4 feet in diameter and only 30 feet deep that could not be surged with compressed air because the casing was made in 4 ft. sections that would not stand surging pressure. Original fears that pumping of the turbid wash water through the strata would result in plugging due to filtering action were proven ungrounded by the 85 per cent increase in capacity.

Fig. 3—SURGING step in well treatment. Vertical pipe is needed when standing water level is high.

Summary

The dispersive effect of the glassy phosphate Calgon on those substances which most frequently plug well screens and the surrounding strata, makes available a most effective agent for cleaning wells. The method is simple and is generally applicable to all types of wells. The chemicals required are readily available, safe to handle and low in cost. The proceedure is useful to help develop new wells or to restore capacity of old wells.

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Fig. 1—DISPERSAL ACTION of Calgon. The 55% slurry of calcium carbonate in water (left) will not flow, but a 70% slurry when treated with Calgon (right) flows readily.

solution containing Calgon and hypochlorite, in amount depending on the volume of the casing, is poured into the well. The hypochlorite is included to alleviate any plugging caused by iron bacteria or other micro-organisms.

Generally, between 15 and 30 pounds of Calgon, and one to two pounds of hypochlorite are used for each 100 gallons of water in the well under static conditions.

With the pump and all other equipment left in place, the chemicals are allowed to remain in the well for 24 to 48 hours. During this period the pump is turned on and off 10 or 12 times at frequent intervals for surging. Fig. 3 illustrates the addition of a vertical pipe to permit surging a well having high standing water levels. If surging is not possible or desirable, equally good results usually can be obtained without surging by allowing the Calgon charge to remain in the well for at least one week.

The surging distributes the chemicals and also produces agitation which helps the Calgon loosen and disperse the deposits. After the last surging the well is flushed thoroughly of waste. The entire procedure should be repeated until no appreciable further improvement is noted. Normally two or three charges are sufficient for a thorough cleaning.

Generally speaking the greatest improvement in well capacity is observed after the first charge. The charge should, however, be repeated for check purposes. There have been cases of wells cleaned with Calgon that did not respond until the third or fourth charge of Calgon was applied. Some wells have required as many as five charges to produce optimum results. The reason for more than one cleaning is that Calgon is relatively slow acting compared with acid and frequently requires considerable contact period before it starts to loosen the cementing material.

Calgon treatment does not solve all well troubles. Obviously, mechanical failures or general depletion of the underground reservoir are responsible for loss in the production of some wells. Although it is rare, one may encounter wells plugged by sand. Calgon will not remove the larger particles of fine sand, although frequently it is found that after Calgon cleaning the sand has been loosened to such an extent that back-pumping will back the sand away from the screen and out into the formation. As far as is known, the only remedies for sand-plugged wells are bailing and mechanical removal.

Reports of Experience

Field experience in cleaning wells with Calgon has been extensive and the treatment has been effective for 80 to 90 per cent of all wells cleaned to date. This is an excellent record, particularly when it is considered that Calgon has been tried many times when the difficulty was actually due to dropping water tables or mechanical failure.

Concrete Wells Retain Capacity

The first reported use of Calgon for cleaning wells was in 1943.[6] This application at a mid-west refinery was undertaken in an effort to find a means of cleaning a porous concrete well where acid cleaning would not be feasible.

Calgon treatment of this and twenty other wells at the same location effectively solved the problem.

The glassy phosphate is quite harmless to either concrete or metal during the contact period employed so that cleaning could be carried out with pumps and other equipment in place. Calgon proved to be safe to handle and no dangerous fumes or gases were generated by its use. Little supervision was found necessary when using glassy phosphate in well cleaning, and the chemical and labor costs were low.

These factors, together with the returning of all but a few wells to original installed capacities, prompted this refinery to establish a routine program for periodically cleaning all wells at intervals dependent on the rapidity of increase in draw down. Indications are that this procedure will prolong indefinitely the life of wells which previously had produced for only about five years.

Increasing Yield of Industrial Wells

At a Baltimore industrial plant, two wells have been cleaned successfully with Calgon. The first, a well less than a year old, originally met the guaranteed flow of 225 gpm only after acid treatment by the well driller. Nine months later, with production having fallen off to less than 150 gpm, the well was treated with Calgon. After cleaning, the output of the well increased to 275 gym without draw down—exceeding output at the initial 225 gpm rate. This well has produced 250 to 275 gpm of water for almost two years without increased drawn down and, in fact, can be pumped at a 300 gpm rate without dropping the level close to the top of the pump bowls.

The second cleaning job at this plant was done on a well approximately ten years old that had been acid cleaned previously. On this well, the output had decreased below 200 gpm and was returned to the original rate of 330 gpm after cleaning. Results on a third well at this plant have been discouraging after two charges were applied.

Municipal Well Treatment

An Ohio municipality has recently reported cleaning a 140 foot well having a 10 inch casing. Tests made before and after cleaning have indicated an increase in pumping rate from about 250 gpm to about 318 gpm, while the draw down decreased from 13.5 feet to 7 feet. This means that the specific capacity in gpm per foot of drawdown increased from 18.4 to 45.5—an improvement of 147%.

R. D. COLE MANUFACTURING CO.

Newnan, Georgia

ELEVATED STEEL TANKS, TOWERS, STANDPIPES, VESSELS.

Established 1854

5,000 TO 2,000,000 GALLON ELEVATED WATER TANKS

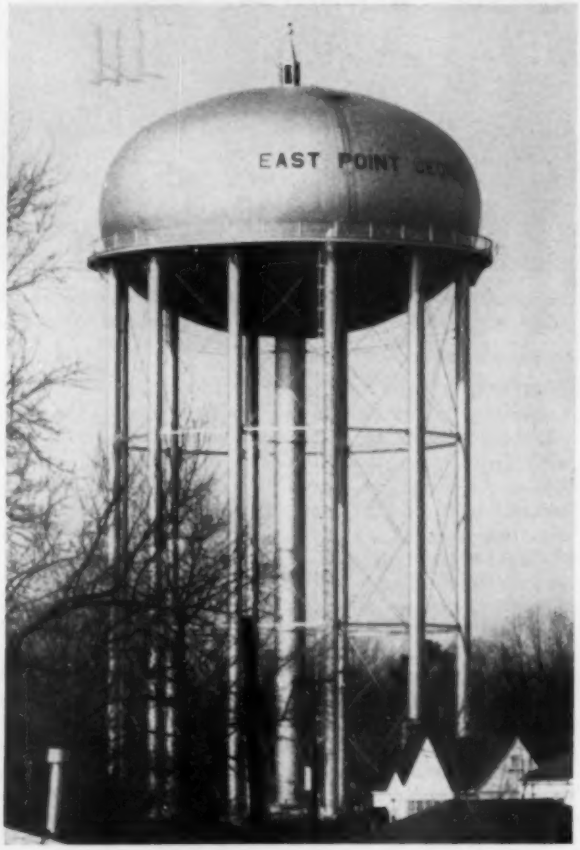
This company has developed a complete line of Elevated Steel Tanks for water supply—both for domestic service and sprinkler requirements—ranging in capacity from 5,000 to 2,000,000 gallons.

Their designs include the standard hemispherical self-supporting bottom, shallow-depth, Cole "Ovaloid", spherical tank on tubular tower, standpipes, and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants, so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oil and gas.

Elevated Steel Water Tanks of All Sizes, Shape and Design.



OTHER PRODUCTS

Other Cole products include tanks, pressure vessels, measuring tanks, processing equipment, lumber treating cylinders, etc., of aluminum, stainless and carbon steels and alloys, built to ASME Code specifications to meet all insurance requirements.

OVER A CENTURY OF EXPERIENCE

Established in 1854, this Company has been supplying American communities and industry with metal tanks, vessels and structures for more than a century. Cole elevated tanks are correct in design. Their simplicity contributes to their low cost of maintenance. Sprinkler tanks and equipment are designed to incorporate the recommendations of all insurance authorities.

A large and experienced engineering department is at the service of prospective customers to assist in solving their problems. Send us your inquiry, stating capacity, height to bottom and location. Write for booklet, "Tank Talks."

DISTRIBUTION

THE ELEMENTS of a complete distribution system include distributing reservoirs, conduits or transmission mains, and pipe lines. Accessories to a distribution system include booster stations, valves, hydrants, main line meters, and service connections.

The importance of distribution systems is indicated by these facts: Pipe lines in water works handle a greater tonnage per day than any other transportation system; approximately 66 per cent of the total value of water works is in the distribution system; approximately 80 per cent of the distribution system value is in mains and valves.

Distributing Reservoirs

The functions of distributing reservoirs are to: Equalize hourly or daily flow; provide and maintain desired pressure in remote areas; and to provide emergency storage for fire protection purposes. Distributing reservoirs also permit equalization of pumping heads, economies of construction, economies of operation, and reduction of pressure fluctuations.

Distributing reservoirs may be of steel, reinforced concrete, earth or wood and may be located at or below ground level (ground storage) or above ground level (elevated storage). Elevated storage may be in tanks or standpipes.

Distributing reservoirs are located at a point near the center of consumption, near areas where improved pressure is needed, on high ground, and on a site that gives greatest advantages for lowest construction costs.

The capacity of distributing reservoirs depends on maximum rate of consumption, maximum pumping capacity, minimum safe yield of source of supply, and fire flow requirements. Reserve storage for fire protection emergency must be provided if pumping capacity is not sufficient to meet requirements for fire flow set by Nat. Bd. Fire Underwriters. Reservoirs float on the system. When pumps operate at average rate, storage tanks fill or empty depending on whether or not the rate of consumption is above or below the pumping rate.

Conduits and Transmission Mains

Water from a supply source or pumping station travels to a distribution net work by gravity in conduits or open channels or in pressure lines termed transmission mains.

Gravity conduits may be canals, flumes, or aqueducts. Pressure lines may be cast iron, steel, reinforced concrete, or wood stave. Transmission lines are located to take the shortest route possible. Pressure lines should avoid peaks and depressions. The size should be based on estimated capacity 25 years in the future. Twin lines are frequently used as a protection in case of failure and to allow cleaning.

Pipe Line Materials

Materials used in distribution systems include cast iron in all sizes, reinforced prestressed concrete (generally in larger sizes) asbestos-cement (generally below 24 in.), steel (generally larger than 36 in.) and wood stave (mainly for irrigation, and industrial supplies).

As a protection against corrosion, metal pipes are lined, either with a coal-tar-pitch varnish (bituminous tar) or cement lining added during manufacture or in place.

Joints for pipe depend on the type of pipe. Cast iron pipe may be bell and spigot, flanged, universal, mechanical, or flexible ball joints. Concrete uses a rubber ring and offset joint forced together under tension. Asbestos-cement pipe uses a rubber ring on a tapered end with the joint covered by a sleeve which holds the rubber ring under compression. Bell and spigot joints are sealed with lead or sulfur joint compounds poured hot against a packing ring of jute, braided paper or rubber.

Fittings include curves or ells (22½, 45, and 90 deg.); reducers, tees, wyes, crosses, and sleeves.

Network Systems

The distribution system consists of three parts: Supply mains, (also termed transmission mains) carry water from source or pump station to sections of a city. Arterial mains are secondary feeders connected to supply mains. Minor distributors make up the gridiron between the arterial mains and supply both domestic consumers and fire hydrants. The location and sizing of mains depend on the area to be served, the number of customers, the required fire flow for the area, number of fire hydrants.

Booster stations consist of pumps which take water from a supply main and discharge it at a higher pressure at another point in the line. Booster stations increase line pressure in outlying areas when head loss is too great in the line. They may be operated in connection with elevated storage tanks and are controlled either by pressure or by a combination of flow and pressure (Pressureflo).

Valves and Hydrants

Valves are located on all branches from feeder mains and between minor distributors and hydrants. They should be placed at least every 1200 ft. on arterial mains and minor distributors and at lesser distances in high value areas.

The types of valves used on distribution lines include butterfly valves, cone valves and gate valves. Check valves are automatic valves that allow water to flow in one direction only. Back flow preventers are special types of check valves used in cross connections between domestic and industrial supplies. Altitude valves in elevated storage tanks to control flow into or out of tank depending on line pressure and water level in the tank.

Hydrants for fire protection service are located according to area to be served, population, district value, length of fire hose that can be served, and method of obtaining required fire pressure. Types of hydrant most commonly used has two 2½-in. hose outlets and one 4-in. pumper outlet. They are located from 2 to 6 ft. from the curb.

Meters and Services

Main line meters (Venturi tubes, Dall Flow Tubes, propeller meters) are used to determine flow of water entering the distribution system or at points of interconnections. They should have high accuracy and low head loss.

Services are small pipes which connect the street mains to the consumer's house. They are usually ¾ to 1½-in. in diameter and may be of galvanized iron, copper, lead, or plastic. Service meters are the cash register of a water works; they may be owned by the utility or by the consumer; they should be checked at regular intervals of 5 to 7 years, oftener if readings appear unusual.

Operators of a distribution system meet many problems such as fire rating, fire flow, pressure, main sizing, main laying, tapping, hydrant and valve maintenance, leak surveys, etc.

Peak Demand Storage*

by GEORGE G. SCHMID

Engineer-Manager, Southeastern Oakland County Water Authority

Royal Oak, Mich.

THERE are some water systems that can meet the peak hour on the peak day without apprehension. To many others, however, peak-hour demand is a challenge of considerable magnitude.

Some smaller communities whose population has remained static, or nearly so, and which possess favorable ground water supplies, have been able to meet peak loads by the use of auxiliary wells, operated during periods of peak demand. If the wells are advantageously located in the community they serve the purpose of storage, but cannot replace its effectiveness. Usually, therefore, a minimum amount of stored water, in either ground reservoirs or elevated tanks, is provided.

Other communities, because of population movement and industrial or other development and expansion, have had increased water consumption, and the extension of water use over a widespread area. Many of these face peak-hour problems, and to them peak demand storage has taken on a new significance.

Under some conditions, if supply and treatment are adequate, improvement can be made by the provision of additional mains and pumping equipment to meet peak loads, but such improvement must be carefully weighed against the possibility of accomplishing the same results by the use of storage designed and located to equalize the load on the distribution system.

Considering that the problem of peak-hour demand exists only for short periods of the year, and is often caused by uses (such as lawn sprinkling or air conditioning) which provide a limited amount of revenue over the year, it is clearly a challenge to decide what should be done to an existing system, and how to do it most economically, without unreasonable duplication of facilities. In any case, storage for peak-load demands deserves serious consideration.

Determining the amount of storage necessary to allow uniform pumping during the peak day and to meet the requirements of the peak hour requires a careful study of local conditions. Records of peak-day and peak-hour consumption provide the best basis for such a decision. If no such records exist, the next best practice is to make an approximation based upon the records or data available for the specific community or for nearby communities with similar problems. In this regard, caution is advisable, however, because hard and fast general rules cannot be applied to every situation. Each community has its own characteristics—topography, street layout, existing water main capacities and locations, sources of supply and treatment, density of population, neighborhood characteristics, and many other factors—which make it necessary that we develop and design storage around the specific needs of the area or communities under consideration.

The system now being constructed by the Southeastern Oakland County Water Authority will be used as an example. Under this system treated water will be purchased from the city of Detroit and repumped through several booster stations into transmission mains of the Authority. From these the water will be metered into distribution mains of the several constituent cities. Both elevated and ground storage will be used. This system can be likened to that of an expanding suburban area containing a number of distribution systems which must be coordinated to function as a unit.

Design Specifications

In the design of the Authority system, the minimum storage capacity was based on the difference between the amount drawn from the Detroit water system (at a rate equal to the average demand for the peak day) and that required to meet the peak hours. The system, which is designed to fill all needs until 1970, will have instruments to record the peak hours; these records will later be used to adjust the original estimates.

Using a 1952 peak-hour day, the minimum controlled storage was determined to be approximately 26 per cent of the total daily requirement (estimated, at the start of operation, as 200 gallons per capita). The data used at this time were not complete, being composite data from seven communities and in various stages of compilation. Most of the communities had enforced sprinkling restrictions and it was never definitely known how severe the peak hour might be if unrestricted sprinkling (which was desired) were allowed. Later, additional records made in 1954 were used to estimate a peak day for 1956, at which time the entire system will be in operation. Table 1 was prepared on this basis and shows the estimated hourly consumption for the peak day. The differences between each hour's consumption and that of the average hour (in both percentage and gallons) and hourly cumulative totals are also shown.

As indicated in the table, the total estimated peak-day consumption for 1956 is 26.4 mil gal with an average hour of 1.1 mil gal, and a peak hour (8-9 p.m.) of 2.19 mil gal, almost double the average hourly consumption. Average-day consumption, for the entire year, was estimated at 12.96 mil gal, or 0.54 mil gal per hour; and for the summer months alone at 17.04 mil gal, or 0.71 mil gal per hour.

The booster stations and transmission mains of the system are designed to deliver a constant output over a 24-hr period based on the estimated peak-day rate for 1970, which is about 42.3 mgd, with sufficient storage, both elevated and ground, to provide the additional output required for the peak hours. The controlled storage capacity will provide the additional amount of water needed to meet the peak hours of the constituent municipalities while they are also drawing from the Authority system at a rate equal to the average demand for their peak days. The constituent municipalities will be responsible for improving their own distribution mains so that they are of sufficient capacity to distribute the water properly to local consumers.

Minimum Storage Needs

According to this design, the minimum storage required to meet the peak hour in 1956 is shown in Column 4, Table 1. The total of those figures which indicate hourly consumption in excess of the average is

*Reprinted from Jour. AWWA. Vol 48, No. 4, p. 378 (1956)

6.44 mil gal, roughly 25 per cent of the total peak-day consumption of 26.4 mil gal. This percentage, which agrees very closely with that of 26 per cent established for the peak day in 1952, is represented by the shaded area in Fig. 1.

Another method of determining this volume has been described by John E. Kiker Jr., Professor of Civil Engineering, University of Florida, Gainesville, Fla.[1]. Figure 2, which shows the amount of storage required using this method, agrees with the previous determination. In the preparation of Fig. 2, the accumulated totals shown in Column 6, Table 1, were used.

If, after the system is placed in service, it becomes evident that the amount of storage cannot meet the peak-hour needs, additional storage facilities will be provided. As indicated, the controlled storage requirement for the summer of 1956 will be about 6.44 mil gal. At this time, the Authority and its constituent municipalities will have 12.5 mil gal in storage, or about twice as much as the estimated demand. With such a margin, there should be sufficient time to forecast any future needs. Additional storage, in the form of another 1.0-mil gal elevated tank, is planned for 1960—or before, if required.

Using the peak-day pumping rates to produce a uniform quantity of water and supplementary storage to meet the peak-hour needs was considered the best procedure for the operating conditions of the Authority system. The method of deduction used is not necessarily a general rule to be followed by others with like problems; other percentages or proportions may be necessary. The best results are obtained when the peculiar needs of the community in question are very carefully studied. Each system may have special characteristics or conditions which affect its peak-hour storage requirements; and what may be ideal for one community may be unsatisfactory for another.

Pumping-Rate Variations

To illustrate how a change in the pumping rate may affect storage requirements, Fig. 3 was prepared. This simple line graph shows the relationship between the percentage of storage required and the maximum rate that the system will produce under different pumping conditions. As previously stated, the Authority system pumping at 100 per cent of the peak-day rate will require about 25 per cent storage. If it were possible to pump at 140 per cent of the peak-day rate, for example, 6 per cent (or 1.6 mil gal) of storage would be needed; and if it were possible to pump at the average summer-day rate, which is about 65 per cent of the peak-day rate, then storage of about 46 per cent (or 12.13 mil gal) would be required. To go to an impossible extreme, if the plant were to pump at the average-day rate, which is about 49 per cent of the peak-day rate, storage of about 56 per cent, or 14.86 mil gal, would be required.

In the design of storage for the Authority system, existing local conditions were given highest consideration. The total storage capacity presently owned by the Authority (including its constituent municipalities) is 3.0 mil gal in elevated tanks. Now being added for use in 1956 is another 2.0 mil gal in elevated tanks and 10 mil gal in ground storage. If elevated storage is assumed to be 50 per cent effective in meeting peak-hour needs, then the total available amount of effective storage in 1956 will be 2.5 mil gal in elevated tanks and 10 mil gal in a ground reservoir, or 12.5 mil gal in all. When the additional 1.0-mil gal elevated tank is installed in 1960, the total storage capacity will be about 30.5 per cent of the design maximum-day (42.3) for 1970, which compares favorably with the 25 per cent estimated for 1956. Of this total, the effective elevated storage of 3.0 mil gal represents 7 per cent, and the ground storage of 10.0 mil gal nearly 24 per cent, of the design maximum-day requirement of 42.3 mil gal.

To summarize, the total storage in the system is about 30.5 per cent of the designed maximum-day requirement: of this, 23 per cent is in elevated tanks, 77 per cent in ground storage. At present, it is believed that these proportions are reasonable, since they are based upon the best data available at the time of design. It should be remembered, however, that certain information (such as the actual severity of peak loads) was not obtainable. Sprinkling regulations in the several municipalities varied widely: in some, sprinkling was permitted on alternate days; in others, not at all. In spite of these factors, the design storage is considered adequate for both present and future needs, with some allowance for contingencies and variations from the original design data.

General Criteria

Some of the factors in the selection of the storage in the system described will be compared with the general considerations of storage. No specific rules or conditions will be defined, for each system has its own peculiarities and requires individual study. Determining the type and volume of storage best suited to a particular system depends as much upon practical considerations as it does upon the performance of routine calculations and assumptions based on rigid rules and formulas.

In the Authority system, the volume of storage was determined to be the additional amount of water required to meet the peak hours while drawing from the source at a rate equal to the average demand for the peak day. It is worth repeating that it would be naive to assume that the ratios and percentages used here could be employed as a general rule for other systems. The use of peak-hour storage to level peak-day demands, however, may have general application.

Storage in sufficient quantity provides a reserve for shutdown and fire fighting. It is a means of increasing the capacity and serviceability of water systems which local development and expansion have made inadequate. Properly located storage will reinforce the weak sections and level the load.

To produce at a greater pumping rate than the peak-day average may necessitate larger transmission and distribution mains and greater investment in booster stations and controls for limited use over the year. If a system with even a minimum of storage is supplied by mains that are not adequate to meet the demand of the peak hour, there will be a drop in pressure and additional pumping equipment will be required.

To produce at a lesser pumping rate than the peak-day average, on the other hand, requires costly additional storage. In the system described, had the production rate been made equal to the average-day requirement for the summer, the designed storage would have been 20 mil gal, or 7 mil gal additional. (This amount in ground storage would have cost $360,000.) Had the production rate been made higher than the peak day for the year, however, and the volume of storage decreased, it might have required day-to-day storage without reserve—an unsatisfactory condition.

A safe procedure, other factors being equal, is to determine the capacity of low-lift pumps and treatment facilities by the maximum-day demand, and the capacity of booster pumping and storage by the maximum-hour demand.

In the absence of good records, assumptions must be made. As a basis

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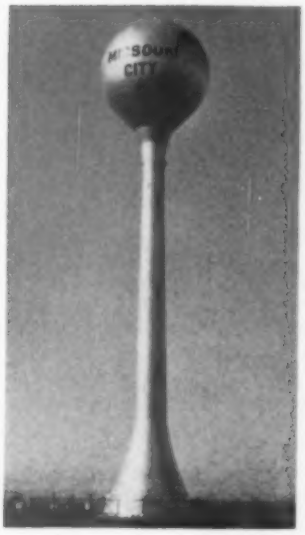
Since 1893, Chicago Bridge & Iron Company has been designing, fabricating and erecting elevated steel tanks and many other types of steel plate work for municipal water systems throughout the country. These 64 years have been years of progress. Tank designs have been constantly improved to provide today's pleasing, streamlined structures.

Tanks for municipal service are built by Chicago Bridge & Iron Company in accordance with specifications of the American Water Works Association. Four strategically located plants in Birmingham, Chicago, Salt Lake City and Greenville, Penn. are always ready to serve you.

HORTON ELEVATED STEEL WATER TANKS

Horton® elevated water tanks are designed to provide dependable gravity pressure in water distribution systems. They usually reduce pressure variations in the mains and often cut down pumping costs.

We shall be pleased to submit estimating figures or quotations on any of the types shown here. When writing please state capacity, height to bottom, range in head, location and shape or design desired. There is no obligation.



ELLIPSOIDAL-BOTTOM WATER TANKS

Ellipsoidal-bottom elevated tanks are relatively large diameter and shallow depth. They are built with cylindrical columns and ellipsoidal roofs.

Gallons Capacity	Tank Dimensions		Gallons Capacity	Tank Dimensions	
	Diameter	Range		Diameter	Range
50,000	22'0"	19'0"	200,000	36'0"	29'6"
60,000	24'0"	19'0"	250,000	40'0"	29'0"
75,000	26'0"	21'0"	300,000	43'0"	30'0"
100,000	28'0"	24'0"	400,000	46'0"	35'0"
125,000	30'0"	25'6"	500,000	50'0"	37'6"
150,000	32'0"	27'6"			

WATERSPHERES

The smooth, streamlined Watersphere presents a pleasing appearance. All piping connections and ladders are located inside the supporting column to which access is provided by a door at ground level. The lower portion of the supporting column may also be used as a pumphouse.

Capacity in Gallons	Diameter of Sphere	Capacity in Gallons	Diameter of Sphere
25,000	19'4"	75,000	27'4"
30,000	20'4"	100,000	30'0"
40,000	22'4"	150,000	34'0"
50,000	24'0"	200,000	37'6"
60,000	25'6"	250,000	40'6"

WATERSPHEROID

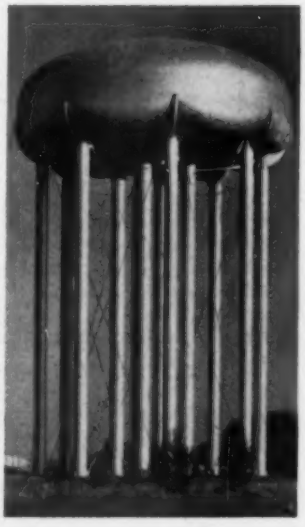
The modern, streamlined Waterspheroid® was designed to combine beauty and service. This elevated water storage tank provides a dependable gravity pressure water supply in a functional, pleasing "package".

Gallons Capacity	Diameter of Tank	Gallons Capacity	Diameter of Tank
250,000	45'3"	400,000	51'6"
300,000	47'0"	500,000	59'0"
400,000	53'0"	500,000	55'6"

RADIAL-CONE BOTTOM WATER TANKS

A functional design that permits large capacity water tanks to be built with a relatively low range in head. They are pleasing in appearance and easy to maintain.

Gallons Capacity	Tank Dimensions		Gallons Capacity	Tank Dimensions	
	Diameter	Range		Diameter	Range
500,000	60'4"	25'	1,500,000	96'0"	30'
750,000	74'3"	25'	1,500,000	88'0"	35'
750,000	67'6"	30'	2,000,000	112'0"	30'
1,000,000	86'0"	25'	2,000,000	102'0"	35'
1,000,000	78'0"	30'	2,500,000	114'0"	35'
1,000,000	71'6"	35'	3,000,000	117'0"	40'
1,500,000	104'0"	25'			

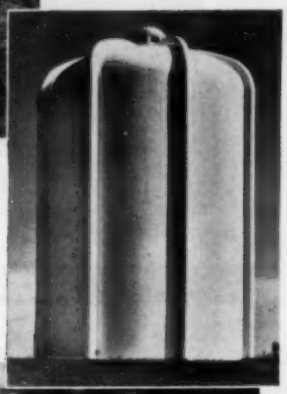


CHICAGO BRIDGE & IRON COMPANY

HORTONSPHEROIDAL WATER TANKS

Gallons Capacity	Tank Dimensions Diameter	Range
1,000,000	87'6"	25'
1,000,000	81'0"	30'
1,500,000	92'0"	35'
2,000,000	106'0"	35'
2,500,000	117'0"	35'
3,000,000	120'0"	40'

Hortonspheroidal elevated tanks are modern, attractive structures. They are built in standard capacities of 1,000,000 to 3,000,000 gallons and are supported either on two rings of cylindrical columns or one ring of cylindrical columns and a large central riser.

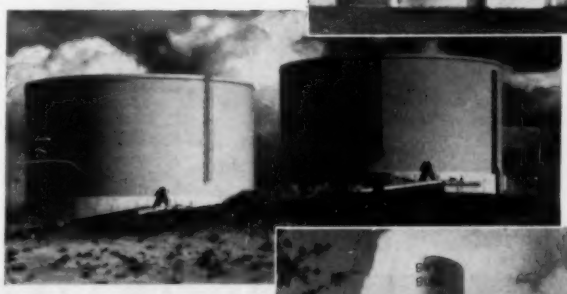


WELDED STEEL RESERVOIRS

CB&I builds welded steel reservoirs and standpipes in standard capacities up to 10,000,000 gals. and in special designs to specified capacities. Careful fabrication and erection assures long service life. Welded construction results in smooth tank surfaces which serve to simplify maintenance.

PHOSPHORIC ACID PROCESS PICKLING AND PAINTING

The Horton phosphoric acid process saves maintenance dollars and prolongs the life of steel plate structures. It removes mill scale before shipment from our plants and helps provide a better bond between the prime coat of paint and the steel. Prime coat is applied while metal is still warm from bath to insure better adherence.

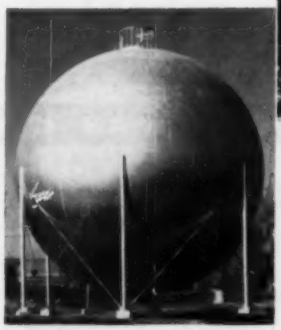


HORTON TRIPOD ELEVATED WATER TANK

For economical gravity water pressure for fire protection and general water service for small municipalities, golf courses and other private water systems. Simplified, functional design provides low maintenance and painting costs—simple foundation. Built in capacities from 15,000 to 75,000 gallons. Standard heights to bottom —15 feet to 125 feet, depending upon capacity.

HORTONSPHERES FOR DIGESTER GAS

Hortonspheres® provide an economical means of storing sewage plant gas under pressure, and thus permit the gas produced in digesters to be utilized effectively. When the *supply* of digester gas exceeds demand, the surplus is pumped into the Hortonsphere. When the *demand* exceeds the supply, gas flows from the Hortonsphere to make up the difference. The entire shell of the Hortonsphere is accessible for inspection and painting. Hortonspheres are built in sizes up to 1,500,000 cu. ft. capacity.



CONKEY SLUDGE FILTERS

Over 2,000 tons of various sludges and industrial wastes (primary, elutriated digested, bio-chemical and industrial) are daily dewatered on Conkey® Sludge Filters. Every municipal and consulting engineer should be acquainted with the advantages and trouble-free performance of Conkey equipment, fabricated by Chicago Bridge & Iron Company.

For QUOTATION: Chicago Bridge & Iron has designed, fabricated and erected all types of heavy steel plate work for water and sewage plants throughout the country. When requesting quotations, we would appreciate receiving plans and specifications.

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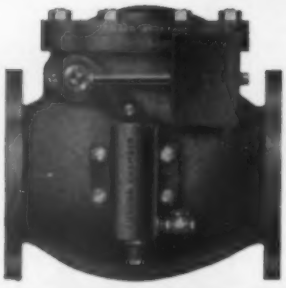
Cushioned Automatic Water Control Valves • Sizes 3" to 36" for pressures to 250 psi

Angle or globe body patterns

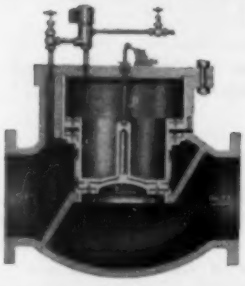
CUSHIONED CHECK VALVES



Swing Check Valve

Cushion chamber on side of body cushions only on last 5% of stroke, prevents any hammer or shock when closing.

Bulletin W-1



Electric Check Valve

Opens only when pump comes up to speed, closes automatically with pump running and shuts down pump when 95% closed.

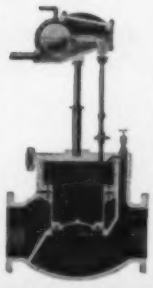
Bulletin W-10

ACCURATE WATER LEVEL CONTROLS

Altitude Control Valve

Maintains water level in elevated tanks within a variation of 3" to 12". May be installed underground.

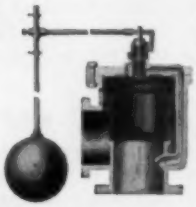
Bulletin W-4A



Cold Water Float Valves

Self-contained float maintains water level in tanks and reservoirs within ½" to 1" variation.

Bulletin W-5



Maintains liquid level control in open tanks, coagulating bins, etc. For high pressure service.

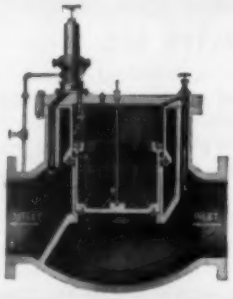
Bulletin W-5

SENSITIVE PRESSURE REGULATORS

Surge Relief Valve

Protects water lines against excessive pressures caused by surges in the system. Fast opening—slow closing.

Bulletin W-2



Water Pressure Reducing Valve

Maintains uniform predetermined delivery pressure regardless of variance in upstream pressure.

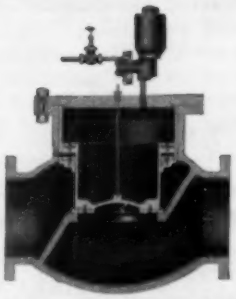
Bulletin W-3A

ONE MAN CONTROL VALVES

Flowtrol Valve

Easily operated by one man regardless of pressure or size of line. Used to replace hard-to-open gate or plug valves.

Bulletin W-8A



Solenoid Valve

Used where remote control operation or operation by electrical impulse is desired. Adjustable opening and closing speeds.

Bulletin W-7A

GOLDEN-ANDERSON VALVE SPECIALTY COMPANY 1254 Ridge Avenue, Pittsburgh 33, Pa.

Descriptive bulletins—numbered under each valve illustrated above—contain complete technical information. Write for your copies.

TABLE I

Estimated Peak-Day Consumption, 1956.

Time	Hourly Consumption gal	Hourly Consumption/ Avg. Hr* %	Variation From Average Hour*—gal		Cumulative Consumption gal
			Above Average	Below Average	
6 AM	0	0			0
7	500,000	45.45	600,000		500,000
8	850,000	77.3	250,000		1,350,000
9	1,200,000	109.1		100,000	2,550,000
10	1,300,000	118.2		200,000	3,850,000
11	1,350,000	122.7		250,000	5,200,000
12	1,400,000	127.3		300,000	6,600,000
1 PM	1,450,000	131.8		350,000	8,050,000
2	1,500,000	136.4		400,000	9,550,000
3	1,650,000	150.0		550,000	11,200,000
4	1,600,000	145.4		500,000	12,800,000
5	1,400,000	127.3		300,000	14,200,000
6	1,600,000	145.4		500,000	15,800,000
7	1,800,000	163.6		700,000	17,600,000
8	2,000,000	181.8		900,000	19,600,000
9	2,190,000	199.1		1,090,000	21,790,000
10	1,400,000	127.3		300,000	23,190,000
11	800,000	72.7	300,000		23,990,000
12	550,000	50.0	550,000		25,450,000
1 AM	300,000	27.3	800,000		23,840,000
2	310,000	28.2	790,000		25,150,000
3	350,000	31.8	750,000		25,500,000
4	250,000	22.7	850,000		25,750,000
5	300,000	27.3	800,000		26,050,000
6	350,000	31.8	750,000		26,400,000
	26,400,000		6,440,000	6,440,000	

*Average hourly consumption was 1,100,000 gal.

on which to proceed, several trial solutions, using anywhere from 20 to 50 per cent of the maximum peak-day demand, should give some indication of the volume of storage required.

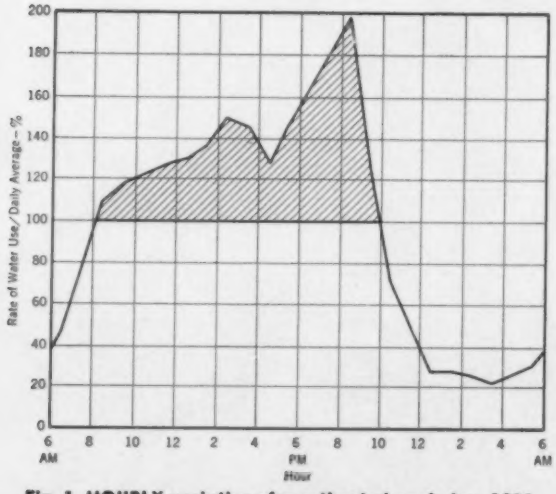


Fig. 1. HOURLY variations for estimated peak day, 1956
The shaded area represents the volume of storage required to meet hourly peak demands, when pumping at the average hourly peak—day rate.

Storage Location

Locating storage at the end of the line opposite the pumping facility, as well as at or near the area of peak demand, permits water to be fed from both ends of the system during periods of peak use, thus (in effect) increasing the carrying capacity of the mains. (It is assumed, in this case, that facilities will be available to permit filling reservoirs during low-consumption periods at night.)

Aesthetic considerations must also be given primary consideration in determining storage location. Elevated tanks in built-up residential areas may provoke local opposition, because of the height of the structure. Sufficient area should be obtained for the site to allow proper landscaping. In many cases it is possible to combine recreational areas—parks or playgrounds—with reservoir sites.

Reinforced-concrete storage reservoirs can be constructed partially below ground level, depending on local conditions. The large steel reservoir used by the Authority, though sufficiently exposed on the sides and top to permit maintenance work, is partially concealed by dikes and landscaping. The elevated tanks used are of the radial-cone type, one of them having a fluted center, which gives it somewhat the appearance of a monument.

Although the storage used by the Authority comprises steel elevated tanks and a steel ground reservoir, consideration was previously given to other types of construction for the ground reservoir. The type selected, however, was considered the most satisfactory within the range of choice dictated by economic considerations.

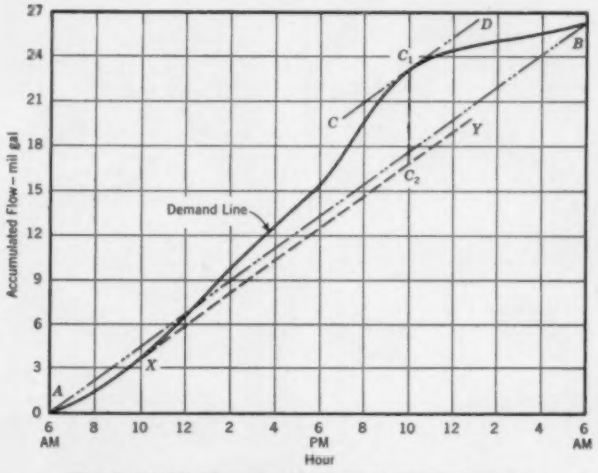


Fig. 2. MASS Diagram of Storage Requirements
The cumulative-demand curve is plotted from records or estimates, and the average-demand line, AB, drawn between its extremities. Lines CD and XY are drawn parallel to Line AB and tangent to the curve at points of greatest divergence from the average. At C_1—the point of maximum divergence— a line is extended down the coordinate to Line XY. This line, C_1C_2, represents the required peak-hour storage: in this case, it scales to 6.44 mil gal.

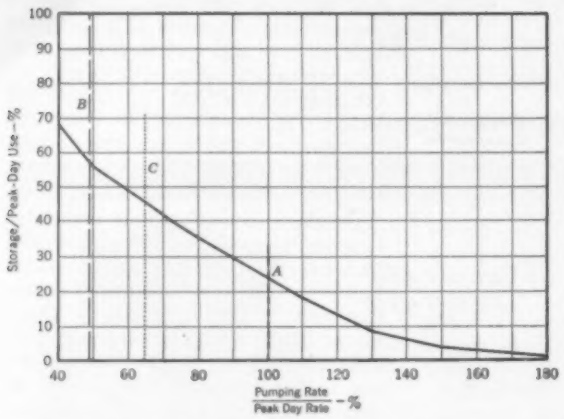


Fig. 3. EFFECT of Storage on Peak-Day Pumping Rate
Line A represents peak-day rate, Line B the average-day rate (figured for the entire year), and Line C the average-day rate for the summer months only.

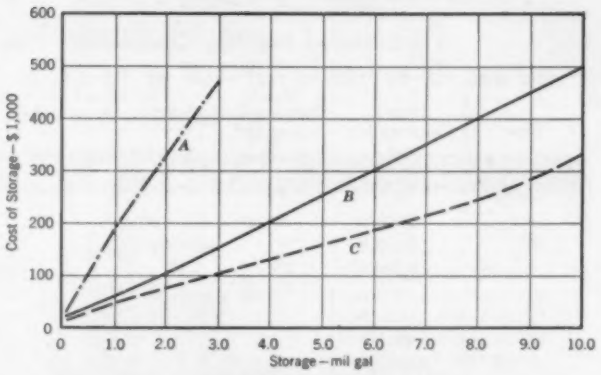


Fig. 4. STORAGE Cost Comparison.
Line A represents the cost of elevated storage, Line B the cost of ground storage (including pumping station), Line C the cost of ground storage without pumping station.

Costs

The difference in first cost of elevated or ground storage can be compared by referring to Fig. 4, which applies to capacities up to and including 10.0 mil gal. The cost of steel elevated tanks up to 3.0 mil gal is compared with that of steel ground-storage reservoirs, including pumping stations. As a general rule, the cost of steel elevated tanks is about 1.5-2.5 times as great as that of steel ground reservoirs (including pumping stations) of comparable capacity. In the Authority system, fortunately, it was possible to combine additional pumping facilities for the ground storage with other pumping facilities, office space, and control equipment in the same building.

In the smaller community, the elevated tank can fill an important need. Always ready to serve with a reserve that does not require repumping, it is especially well suited, for example, for fire-fighting requirements. Usually, normal pumping operations is possible with its use. It is only during peak hours that elevated storage may be materially exhausted. The size of the tank should be determined by the pumping capacity of the station, but it should not be so large that it cannot be filled during the night hours of the peak day. In the larger community, a certain percentage of storage in elevated tanks is useful to maintain level pumping loads and permit more reliable pumping control.

Among the chief advantages of ground storage is that it can be filled more rapdily than elevated tanks With ground storage reservoirs in the smaller community, manual controls—requiring attendance at the site of operation—may be most suitable; in larger installations, however, the use of automatic controls may be preferred.

Either type of storage may be located near the area of peak demand and filled at night, permitting more efficient use of pumping equipment and water mains. Sometimes this practice may result in reduced power costs, since the required pumping is performed at an hour when power loads are at a minimum. The cost of repumping from ground reservoirs is also an important factor in selecting a storage facility. This cost, however, should not be excessive if repumping is required only for periods of peak consumption.

The type and volume of peak-hour storage best suited to any given system will be determined largely by the nature of the existing facility, and the special needs and conditions of the community served. Of the experience here described, at any rate, it may fairly be observed that peak-hour storage is to peak-hour demand as green is to grass.

Reference

1. KIKER, JOHN E. JR. Computing Requirements for Elevated Water Storage. *Public Works*, 5:74 (May 1953).

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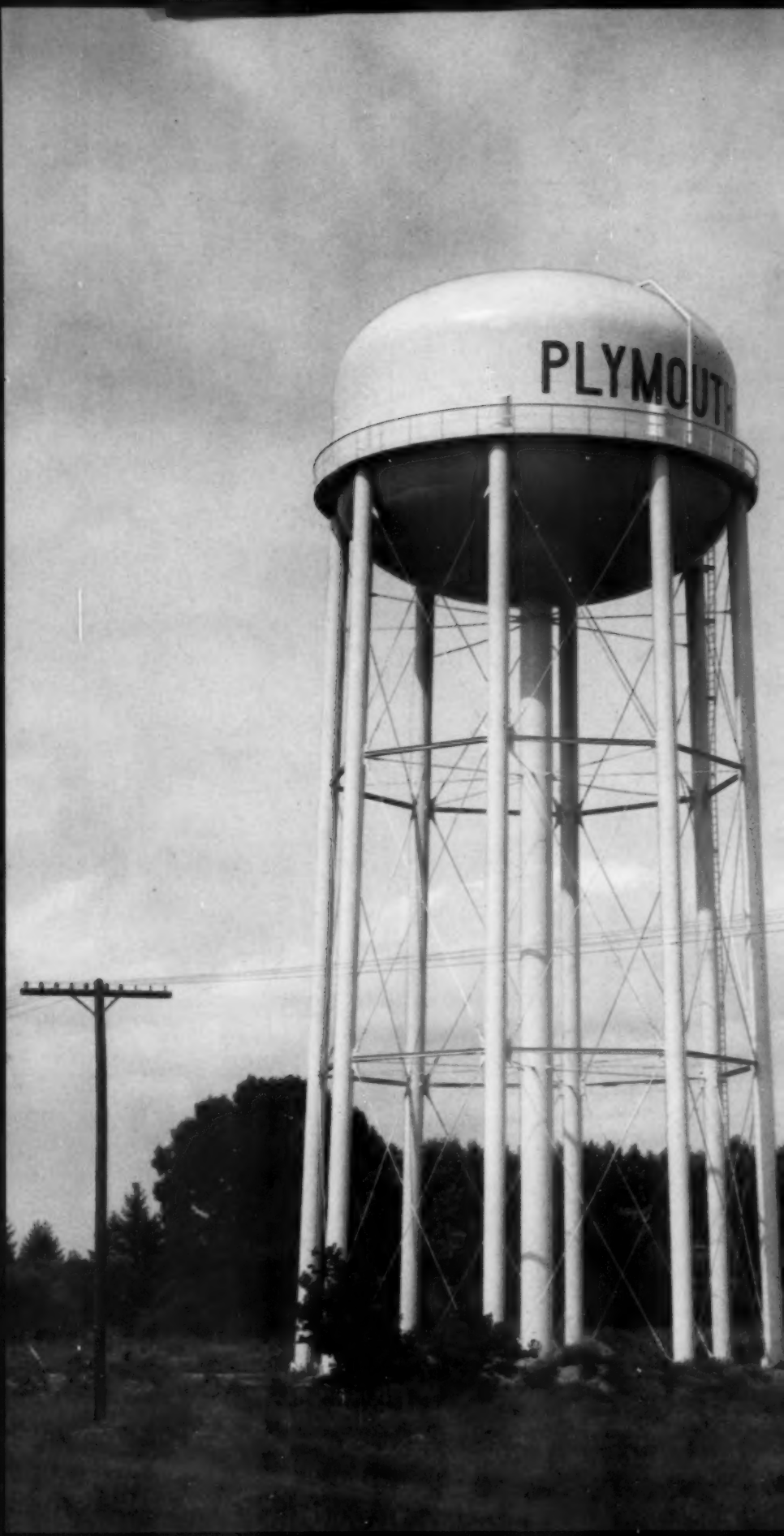
PLYMOUTH

FILE REFERENCE

FACT SHEET

GRAVER®

Elevated Water Tank for the City of Plymouth, Indiana

Ralph Lentz, Water Works Superintendent
Clyde E. Williams & Associates, Inc.,
Consulting Engineers, South Bend and Indianapolis, Ind. and Lansing Mich.
Lloyd Taylor, Project Engineer
Graver Tank & Mfg. Co., Inc.,
Design, Fabrication and Erection

Type: Double Ellipsoidal Elevated Tank
Capacity: 400,000 gallons
Height of Overflow: 130 feet
Low Water Level: 100 feet
Diameter of Tank: 50 feet
Built to AWWA Specifications, except that ¼" plate was used on the roof instead of ⅜" minimum
Painted and Sterilized

THE PROBLEM

A water supply system designed to serve a rural county seat of 3,838 people was woefully inadequate for today's population of 6,704 in this thriving trading center. One industry alone consumed one-third of the water. And the situation was further complicated by a disasterous flood in 1954 which polluted the city's wells located near the Yellow River. Steps had to be taken without delay to meet the problem.

THE SOLUTION

Anticipating probable population and commercial requirements by 1980, plans were developed for new wells, larger mains, and adequate pumping and storage capacity. Standards of the National Board of Fire Underwriters indicated a fire pumping formula of 150% of the flow required for normal domestic use, plus 10 hours of fire flow. The desirable storage capacity was set at 500,000 gallons, 100,000 gallons in an existing tank and 400,000 gallons in a new tank.

Graver was selected to design, fabricate, erect, paint and sterilize the new 400,000 gallon elevated water tank.

The close teamwork of the city's water works superintendent, the consulting engineers and the Graver organization speeded the elevated water tank erection so that the new water system could be put into operation in 1956.

If you have a water storage or pressure problem, it would be well to talk it over with a qualified consulting engineering firm and Graver, whose 100 years of experience in tank fabrication and erection can contribute measurably to your plans.

GRAVER TANK & MFG. CO., INC.

EAST CHICAGO, INDIANA

New York • Philadelphia • Edge Moor, Delaware
Pittsburgh • Detroit • Chicago • Tulsa • Sand Springs, Oklahoma • Houston • Los Angeles
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A CENTURY OF CRAFTSMANSHIP IN STEELS AND ALLOYS

GRAVER

DESIGNED, FABRICATED AND ERECTED BY

GRAVER ELEVATED WATER TANKS

Graver elevated water tanks are expertly fabricated from carbon steel, stainless steel or aluminum at Graver plants across the country and are erected on the site by experienced Graver crews to the highest welding standards.

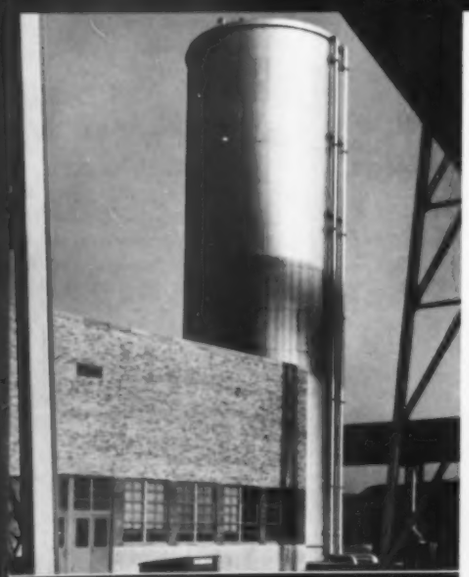
The selection of one of the standard sizes shown in the table offers the advantage of lowest cost and quick deliveries. Should one of the standard sizes not be suitable, special designs by Graver's engineers is a regular service.

Capacity Gallons	Diameter	Head Range	Number of Columns
25,000	18′ 0″	13′ 9″	4
30,000	18′ 0″	16′ 6″	4
40,000	20′ 0″	17′ 10″	4
50,000	22′ 0″	19′ 0″	4
60,000	24′ 0″	19′ 0″	4
75,000	26′ 0″	21′ 0″	4
100,000	28′ 0″	23′ 9″	4
125,000	30′ 0″	25′ 9″	4
150,000	32′ 0″	27′ 11″	6
200,000	36′ 0″	29′ 11″	6
250,000	40′ 0″	29′ 2″	6
300,000	44′ 0″	30′ 0″	6
400,000	50′ 0″	30′ 0″	8
500,000	52′ 0″	35′ 0″	8
500,000	55′ 0″	30′ 0″	8
600,000	55′ 0″	40′ 0″	8
600,000	61′ 0″	35′ 0″	8
750,000	61′ 0″	40′ 0″	8
750,000	65′ 0″	35′ 0″	8

Graver is an approved fabricator of pump suction tanks under the Factory Mutual Fire Insurance Companies specifications. All standard sizes shown in the table have ¼″ bottoms, 13/16″ self-supporting roofs and shells of thickness such that stress does not exceed 15,000 psi.

Rated Capacity Gallons	Actual Capacity Liquid Depth = Height—6″	Diameter	Height
100,000	100,470	27′ 0″	23′ 11½″
150,000	150,120	28′ 6″	31′ 11½″
200,000	200,730	33′ 0″	31′ 10½″
250,000	250,340	37′ 0″	31′ 7½″
300,000	300,550	42′ 0″	29′ 6″

GRAVER PUMP SUCTION TANKS



GRAVER STANDPIPES AND RESERVOIRS

Water supply storage tanks whose height exceeds the diameter are referred to as standpipes. When the diameter exceeds the height, they are called reservoirs. Standpipes normally provide static head to the water distribution system; reservoirs usually are intended for storage and reserve supplies. For both types of water tanks, there can be no standard sizes offered. Since the size and form depend upon local conditions and individual requirements, standpipes and reservoirs must be designed in accordance with the special needs of the users and the characteristics of the site.

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Inspecting and Repainting Steel Water Tanks

by J. O. JACKSON
Retired Vice-President in charge-of engineering and research for Pittsburgh-Des Moines Steel Co.

THE SERVICE LIFE and economical maintenance of steel water tanks depends upon thorough regular inspection and upon prompt and thorough repair and repainting as necessary. Aside from possible damage by floods, storms, or earthquake, the life of a steel tank is limited only by the damage due to corrosion of the tank plates and the supporting tower, if any.

The American Water Works Association's Specification D102, "Tentative Recommended Practice for Painting and Repainting Elevated Steel Water Storage Tanks, Standpipes, and Reservoirs," was prepared by a joint committee representing the American Water Works Association, the New England Water Works Association, and the American Welding Society. It is recommended as a guide to the owner of the tank, as to inspection, repair, repainting, and attendant contractual arrangements. Repair and repainting are such specialized and somewhat hazardous undertakings, particularly for elevated tanks, that they are seldom done by regular maintenance personnel. Instead, these functions usually are performed by contractors who are experienced in this work.

Inspection and Report

All tanks should be thoroughly inspected inside and outside at least once each year, preferably in the spring, to determine the extent of pitting or of paint failure by blistering, peeling, rusting, or abrasion (as by ice). The outside of a tank and its supports should be inspected for possible structural damage after every serious storm, flood, or earthquake. If the regular maintenance inspection is made in the springtime, the repairs and repainting, if needed, may be contracted for in time to have the work done under favorable summer conditions. The inspection should be done by the owner's maintenance superintendent, his engineer, or by any other competent and experienced in recognizing conditions which are or may become serious. Consulting structural engineers and many testing laboratories offer inspection services. Tank manufacturers usually offer such service for tanks of their manufacture.

The tank should be completely drained for the inspection. The interior surfaces should be washed down with a fire hose, to remove the slime from the walls. All dirt should be cleaned out from the bottom. Suitable rigging, to enable the inspector to check all parts of the structure, is essential. The detailed inspection report[1] should include an evaluation of the condition and recommended repair and/or repainting of the following: foundation(s), riser pier, anchor bolts and nuts, column bases, columns, sway rods, tower alignment and general condition, riser, frost casing (if any), ladders, balcony, struts, tank bottom, walls, roof, overflow, level indicator, heater (if any), valves, etc. Extreme care should be exercised during the inspection. Interior ladders and spider rods are usually the first items to deteriorate to unsafe conditions.

The report on the condition of the paint, or other protective coating, should include a description of the type of failure, if any, such as blistering, peeling, flaking, alligatoring, chalking, rusting, and the extent thereof in per cent and degree.

The report should include an estimate of the useful life remaining in the tank. The extent and depth of pitting is important: whether localized in spots which can be repaired by welding, or whether the pitting is general, requiring new sheets or structural members. If steel is required, the amount and location in the structure should be stated.

Action on Report

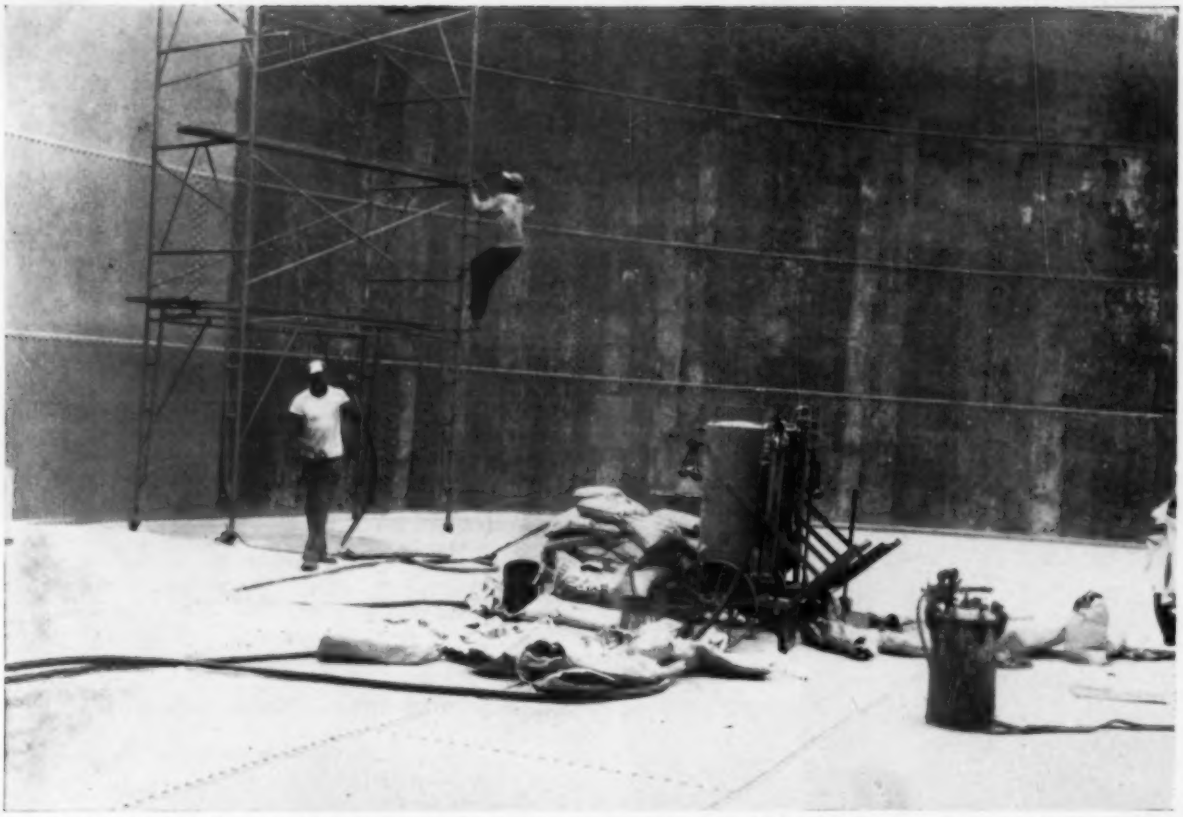
The report should be held confidential and should be made only to the persons who have ordered the inspection. Having received the report the person responsible for the maintenance of the tank will probably discuss the required repairs with the inspector and then plan the work accordingly. If the repairs consist only of things the owner can take care of with his own maintenance force, orders should be issued to have the work done and the report should be noted to indicate that each item was properly taken care of. If the repairs are extensive the owner may wish to advertise for bids and have the work done by some competent organization. It is of great importance to contract with an organization who will do the work conscientiously at a reasonable price.

If the tank is used for sprinkler or fire protection service, the insurance company and the local fire department should be notified when the tank is to be taken out of service and how long it will be out, so that special provision can be made for emergency water supply in case of fire.

Painting

If the tank needs a complete repainting and if the previous paint system gave good service, it is wise to continue the use of the same system, including the corrosion inhibitive primer, intermediate, and topcoats. If the previous paint system gave unsatisfactory performance, the selection should be based upon the recommendations of the Steel Structures Painting Council in their recently published "Painting Manuals."[2] This Council is made up of representatives of 19 national associations or technical societies, including, of particular interest here, the American Water Works Association, American Institute of Steel Construction, National Association of Corrosion Engineers, National Paint Varnish and Lacquer Association, and the Federation of Paint and Varnish Production Clubs.

Volume 1 of the "Painting Manual" includes a chapter entitled "The Painting of Steel Tanks." Volume 2



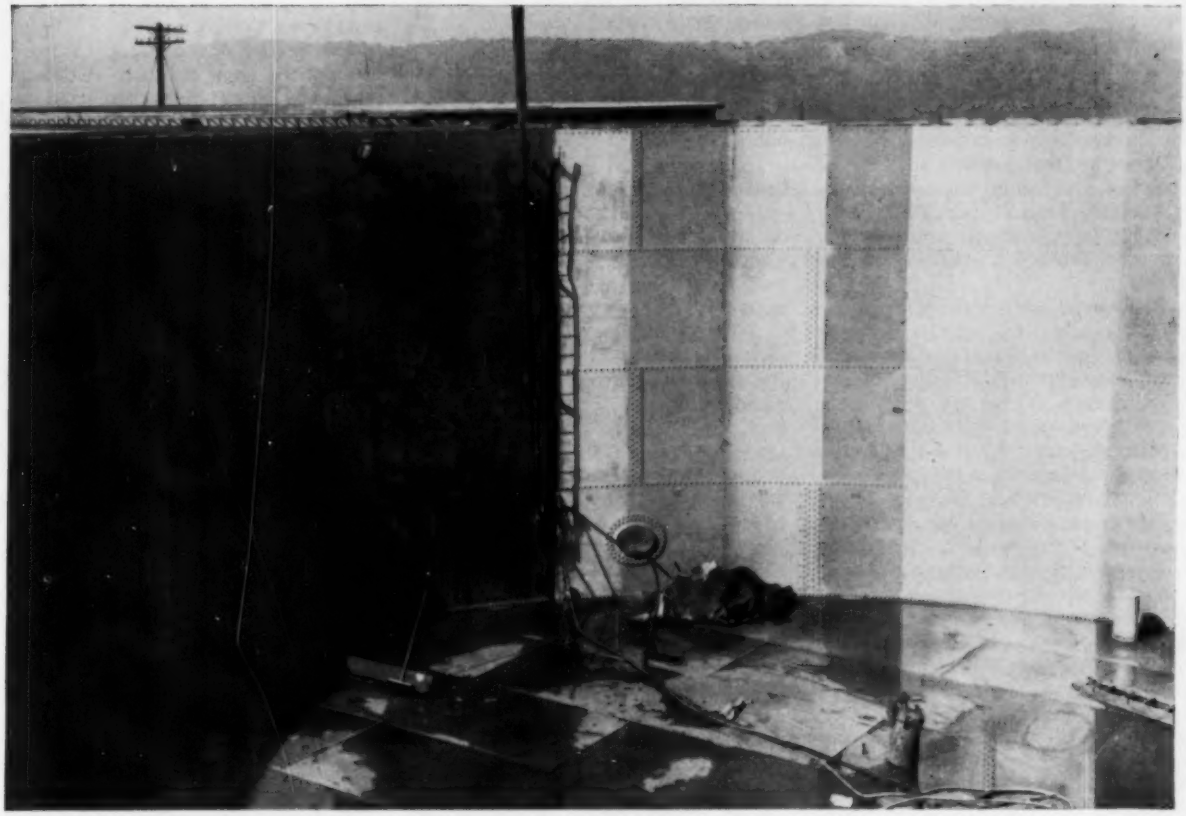
BLAST CLEANING badly corroded steel tank. Blast machine at center. Movable scaffold on castors can be dismantled for removal through man-hole. Note blast-cleaned area at left.

was published to fulfill the need for specific recommendations for the painting of various types of steel structures, to supplement the general recommendations of good practice found in Volume 1. Included are nine SSPC Specifications on surface preparation, covering wire brushing, blasting, pickling, etc. There are four SSPC surface pretreatment specifications, covering wetting oils, vinyl washcoats, and hot and cold phosphate treatments. There are thirteen SSPC primer specifications and seven SSPC intermediate and/or topcoat specifications, as well as an extensive index of Federal, Military, and ASTM specifications on paint.

TABLE I

Recommended Paint Systems

Schedule	A	B	C	D	E
(A) INTERIOR SURFACES					
SSPC Paint System No.	SSPC-PS4-55T	SSPC-PS3-55T	SSPC-PS3-55T	SSPC-PS3-55T	SSPC-PS1-55T
Surface preparation	Blast	Blast	Blast	Blast	Wire brush
Pretreatment	Vinyl washcoat	Vinyl washcoat	None	None	None
Primer(shop or field)	Vinyl red lead	Vinyl red lead	Phenolic chromate	Phenolic red lead	L. O. red lead
Intermediate coat	Vinyl red lead	Phenolic enamel	Phenolic enamel	Phenolic red lead	Red lead-litharge
Topcoat	Vinyl aluminum	Phenolic enamel	Phenolic enamel	Phenolic red lead	Red lead-litharge
(B) EXTERIOR SURFACES					
SSPC Paint System No.	SSPC-PS4-55T	SSPC-PS2-55T	SSPC-PS2-55T	SSPC-PS2-55T	SSPC-PS1-55T
Surface preparation	Blast	Blast	Blast	Blast	Wire brush
Pretreatment	Vinyl washcoat	Vinyl washcoat	None	None	None
Primer (shop or field)	Vinyl red lead	Vinyl red lead	Phenolic chromate	Phenolic red lead	L. O. red lead
Intermediate coat	Vinyl red lead	Alkyds	Alkyds	Alkyds	Alkyds
Topcoat	Vinyl-alkyds	Alkyds	Alkyds	Alkyds	Alkyds



CONTRAST of badly corroded surface (left) and blast-cleaned and painted surfaces (right). The grey strips have been blasted, but not yet painted.

There are nine broad SSPC specifications covering paint systems, covering oil base, alkyd, phenolic, vinyl, bitumastic, etc., for various exposure conditions, such as "normally dry but exposed to weather," "frequently wet or exposed to high humidity," "continuously wet or immersed in fresh water," etc.

These two volumes reflect the enormous task of the correlation of the best factual data and experience on the technical, practical, and economic aspects of paint protection of steel structures such as water tanks. The SSPC Specifications are earnestly recommended for attention. The incorporation or even partial use or reference thereto, of these specifications by the purchaser of a water tank, by maintenance superintendents, engineers, or other authorities, in the technical provisions of a repainting contract, cannot help but result in better performance and service for the tank owner.

TABLE 2

Specifications for Painting and Surface Preparation

Item	Pertinent Specifications
Blast cleaning	SSPC-SP-52T, "Commercial Blast Cleaning"
Wire brushing	SSPC-SP2-52T, "Hand Cleaning," or
Tool Cleaning	SSPC-SP3-52T, "Power Tool Cleaning"
Vinyl washcoat	SSPC-PT3-53T, "Basic Zinc Chromate-Vinyl Butyral Washcoat"
Vinyl red lead	MIL-P-15929A, "Primer, Vinyl Red Lead Type"
Vinyl aluminum	SSPC-Paint 8-55T, "Aluminum Vinyl Paint"
Vinyl-alkyds	Wide choice of color and shade; see p. 198, SSPC Volume 2.
Phenolic chromate	Pittsburgh-Des Moines S16482 (proprietary)
Phenolic enamel	Pittsburgh-Des Moines F16502 (proprietary)
Phenolic red lead	TT-P86a-Type IV, "Paint, Red Lead, Phenolic"
L. O. red lead	TT-P86a-Type I, "Paint, Red Lead, Linseed Oil"
Red lead-litharge	TT-P86a-Type I, plus litharge
Alkyds	Wide choice of color and shade, including: SSPC-Paint 101-55T, "Ready-to-Mix Aluminum Alkyd" SSPC-Paint 102-55T, "Black Alkyd Paint" SSPC-Paint 104-55T, "White or Tinted Alkyd Paint"
Application	SSPC-PA1-53T, "Shop, Field, and Maintenance Painting"

Paint Systems

There are no foolproof paint systems for the protection of steel tank surfaces. After more than a quarter century of research and testing of surface preparation, pretreatment, paints, paint systems, and paint application, in the laboratories of the author's company and in actual service, the paint systems given in Table 1 have been found to give very good performance under average service conditions[3,4,5,6].

These paint schedules are consistent with the SSPC recommendations. Schedules D and E will be recognized as being in conformance with AWWA recommendations in their

Specification D102-52. The pertinent specifications covering the surface preparation, pretreatment, primer, intermediate coat, and topcoat, and their application, are given in Table 2. All of the paints listed therein are readily available from many sources, but none are trade sale or shelf items. Some of the paints are available as proprietary brands, but all are the so-called specification paints which are formulated for specific applications.

Paint schedule A is a complete vinyl system. All coats must be sprayed, preferably by painters who have had experience with lacquer-type coatings. There are proprietary brand vinyl paints available which contain the same film-forming ingredients as the standard spraying formulations, but which include higher boiling point solvents for brush application. Spraying with vinyls does not result in paint sticking on nearby autos or other structures, because the overspray dries within a short distance.

Paint Schedule B is vinyl shop primed but non-vinyl field paint system. It is used where local painters with vinyl or lacquer experience are not available. Striping and spotting with the "shop" pretreatment and primer is done by flow brushing.

Paint Schedule C has been one of our best standards for about 20 years and is useful where a low initial cost is necessary. The interior phenolic topcoat must be applied over the phenolic intermediate coat within 12 to 14 hours to get satisfactory adhesion between these two coats. The topcoat paint must otherwise be reduced with strong solvent, such as cellosolve or methyl isobutyl ketone, using not more than one pint per five gallons of paint, to soften the intermediate coat.

Paint Schedule D is the AWWA phenolic red lead system. The same "adhesion" precaution applies as for Schedule C, as well as for all phenolic systems.

Paint Schedule E is the AWWA linseed oil-red lead system, and is the only system which does not require optimum surface preparation, as by blasting. Litharge is added to the red lead paint, just prior to application, to speed up drying and hardening.

After repainting is finished, the owner is, of course anxious to fill the tank with water. If drying and ageing depends upon natural ventilation, on the very poorly ventilated interior surfaces, and unless a large volume air mover or blower is used, the following minimum drying times, based upon past experience, are required: one day for the vinyl topcoats, one week for the phenolics, and 30 to 60 days for oil base topcoats. This obviously influences the selection of interior paint systems and, of course, the type of surface preparation.

All of the paint systems discussed comprise three coats of paint because it is felt that a total dry film thickness of at least 4 mils is necessary for satisfactory paint service life before complete repainting is again necessary. A total of 5 mils is economically justifiable, from the standpoint of maintenance cost per square foot per year. The comparative total initial costs of the various systems are of the order of $0.40, $0.35, $0.28, $0.30 and $0.29 per square foot of painted surface, respectively, corresponding to comparative maintenance of about $0.08, $0.09, $0.10, $0.10 and $0.11 per square foot per year for paint Schedules A, B, C, D and E, in that order.

This review of repainting has been confined to paint as such. Although there are many tanks protected by coatings such as wax, grease, and coal tar, hot or cold applied; by neoprene, cement linings, sprayed metal, either zinc or aluminum, with or without seal coats; and by cathodic protection, with or without painted surfaces, the large majority of maintenance is based upon paint.

Summarizing, successful and economical paint protection depends upon:

1. Selection of a suitable paint system.
2. Proper surface preparation.
3. Suitable and compatible paint materials.
4. Good application to minimum film thickness under favorable working conditions.
5. Adequate drying and ageing.
6. Maintenance of the paint system by alert inspection and spot repair or complete repainting.

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How To Thaw Frozen Water Pipes*

by DEWEY JOHNSON

Engineer, Cast Iron Pipe Research Assn., Chicago, Ill.

FROM TIME to time, practically all northern water utilities are faced with the task of thawing frozen service pipes and small diameter water mains.

Although the original mains and services may have been installed below frost depth, later construction activities, such as the regrading of streets, parkways and sidewalks, and the building of new subdivisions, often remove part of the earth protection and permit the pipes to freeze.

The most common method of thawing frozen services is the use of electric current. Developed several decades ago, this method has been widely used in severe winters since 1918.

Usually an electric welding unit serves as the source of current, although utility current is sometimes used. The welding unit, incidentally, is a good piece of equipment to have available the year around for miscellaneous repair jobs. These portable units are driven by gasoline engines ranging from 30 to 100 horse power, with generators having a capacity as high as 800 amperes.

In the thawing operation, it is the amperes that are important. Voltage needs only to be high enough to push current through pipe being thawed.

The principle behind the operation is simply this: use sufficient electric current to raise the temperature of the pipe metal high enough to melt ice.

In years past, similar results were obtained by using small steam boilers with proper diameter hoses and small needle pipes to force steam or hot water into the services. This procedure may still be necessary where nonmetallic mains are used.

Service pipes may be thawed with only 200 or 300 amperes in a few minutes, with voltage ranging from 10 to 40. A six-inch water main, on the other hand, may require 500 to 600 amperes at 60 volts, and take two or three hours for thawing.

Often a considerable length of time and rather high amperage is also required to melt ice and permit water to flow in copper service pipe, which has excellent conductivity. Sometimes it is necessary to dig down to the corporation stop at the mains and attach thawing wire to the copper tubing.

One of the power wires leading from the electric generator should be connected to the service pipe in the house and the other wire to the water main in the street, either by attaching it to a fire hydrant or to the water service of a nearby house. All pipe joints in the circuit should be reasonably good electric conductors.

Some trouble has been experienced in thawing services attached to mains on which lead substitute joint material has been used. Sulphur compounds in sandy soils, for example, or in other soils having high resistivity, have proven rather difficult to thaw. Cities using sulphur compounds in cold climates should drive a lead wedge at least 2" in length into the bell before pouring the compound. Possibly two 1½" wedges would be more effective. Wires coming from the electric generator should be at least 000 in size.

Before the thawing wire is attached to the water service pipe, both the water meter in the house and the grounded neutral electric wire used by many electric and telephone companies should be removed. Then occupants of the house should be cautioned about touching electrical appliances and gas piping.

If the second thawing wire is attached to the water service in the adjacent house to complete the circuit, the water meter and neutral wire of this house should also be removed.

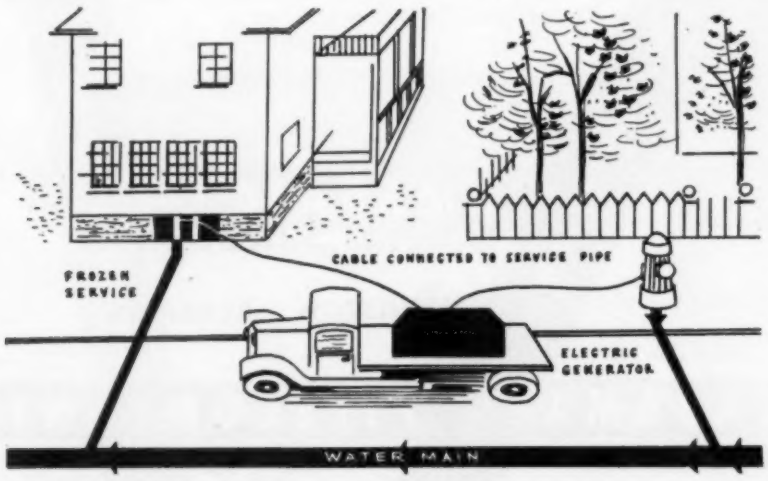
In conducting the thawing operation, the use of more than 600 amperes at 60 volts should be avoided. A greater current creates hazardous fire conditions and the possibility of accidental shock to people living in the buildings involved.

There have been cases where as much as 1500 amperes was applied to copper services to hasten thawing. This high amperage is definitely on the dangerous side, and should be used only by experienced technicians. Six-inch mains provided with lead joints or lead-tipped rubber gaskets are commonly thawed with currents ranging from 500 to 600 amperes.

Since many telephone companies ground their instruments to water service pipes, house phones should be inspected to see that ground wires are removed during the thawing operation.

In general the electrical method of thawing frozen water pipes is the most easily and quickly applied of methods in service today. Handled by qualified workmen, this method creates no dangers for occupants of houses involved.

*Reprinted from Cast Iron Pipe News—Mar.-April. 1956.



TYPICAL electrical hook-up used in the north to thaw frozen water service pipe.

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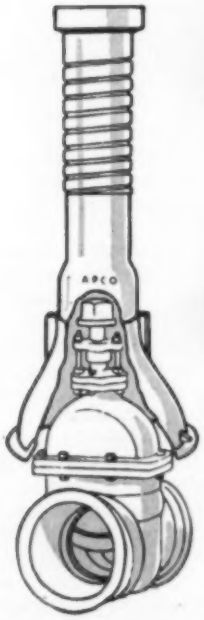

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Cleaning Water Mains*

by J. A. FRANK

Vice-Pres.-Genl. Mgr., National Water Main Cleaning Co., New York, N. Y.

THIS article is designed to explain and illustrate the "why, when, and how" of cleaning and lining water mains. When the carrying capacity of mains decreases, there is a decrease in the serviceability of the system. The need to recover water main capacity is "why" water mains are cleaned.

The curves, Figs. 1 and 2, show the population increase of all the cities in the Southwest Section which reported answers to an AWWA questionnaire, both in 1945 and in 1950. Fig. 1 illustrates trends of cities below 400,000 and Fig. 2 for those of cities above 400,000 population levels.

Examining two sets of curves, we find that there are two cities having negative slopes, indicating loss of population; these two exceptions were caused by military installations which were inactive after World War II. Consideration of the slopes of these trend curves indicates that the rate of increase of population becomes increasingly rapid as the population becomes greater.

Increasing Water Consumption

Fig. 3 illustrates the demand for water shown by these cities. The demand, as figured here, is the product of the population times the per capita water consumption. By reexamining Figs. 1 and 2, it will be apparent that the demand is cumulative: as the population increased, the per capita water consumption increased at a faster rate. Thus, the slope of the curves in Fig. 3 is much greater than the slope of the population curves; as pointed out before, the per capita water consumption increases more rapidly as the population increases and, therefore, the slopes on Fig. 3 are a reflection of the cumulative effect of increasing per capita water consumption at the same time the population is increasing.

Unaccounted-for Water

Also to be noted is the fact that the slope becomes steeper and steeper as the city grows larger in population. In plotting these data, the unaccounted-for water (the difference between the total quantity produced and the total amount sold) varies; in some cases the amount is as high as 40 per cent. It is interesting to note that, in the cities where the unaccounted-for water is held to 15 per cent or less, each city has had Pitometer surveys made.

Fig. 4 conclusively indicates the demands on the water distribution systems have become greater and greater. New pipe to take care of this growing demand has not been laid as rapidly as the demand has increased.

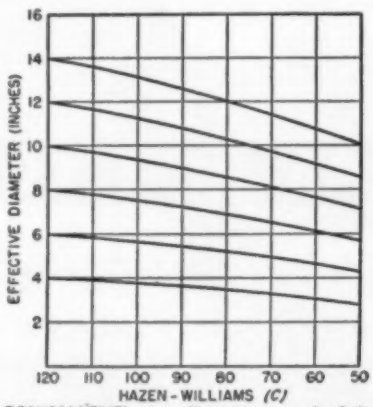
The loss of coefficient for the various sizes of pipe as predicted in the Hazen & Williams Handbook is illustrated in Fig. 4. Note that this is a family of curves, and that the centroid of the family has been drawn as a heavier line. The significant point to be noted is that, while the demand on the systems has been going up and up, the coefficients or ability to supply demand has been decreasing at the rates shown.

The equivalent diameters required for pipes as they lose coefficient is illustrated in the Hazen-Williams "C" valve graphs reproduced herewith. Since the total investment in water mains in the U. S. is estimated at four and one-half billion dollars, a tremendous amount of capital investment is being lost due to loss of coefficient.

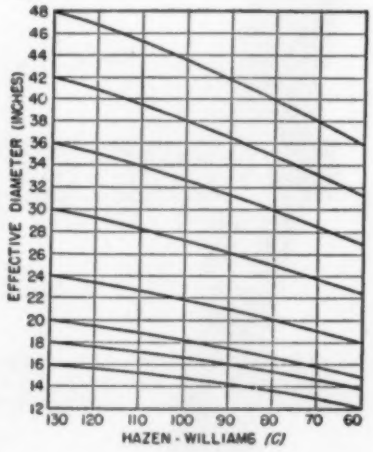
In short, the load on the water lines is increasing at a very rapid rate, which is cumulative, and that the ability to serve (the capacity of the pipe lines) is dropping at a very alarming rate. Thus, if we can recover the loss of coefficient, and the resultant loss of capacity, we are then in a position to improve and recover this loss in capital plant.

Water Main Cleaning Methods

The process of water main cleaning can be divided into the "drag method" for lines of 4 and 6 inches, and the "pressure method" for lines 8 in. and larger.



EQUIVALENT pipe diameters required for specific "C" values.



Charts courtesy of Clinton Inglee, reproduced from Jour. A.W.W.A.

* A revision and condensation of an article by J. A. Frank and A. G. Perkins published in 1954.

Drag Method

After preliminary work, such as excavation, notification, etc., the drag work process consists of isolating the main to be cleaned, then making a cut at the entrance point and a cut at the exit point. The nipples cut out of the main usually are 28-in. in length.

A light cable is extended through the water line from one end to the other, either by means of jointed rods or a piston-like device called a carrier. A "make-up," which allows temporary repair at the starting point, and a stuffing box are next installed. The water pressure in the main propels the carrier, which drags the light line through the main behind it.

After the light cable is run through the main, the cable from a power winch, usually ⅜-in. in diameter, is pulled back to the starting point and the "drag" tool is attached to this heavier cable. After the cleaning tool is pulled into the main, entrance to the main at the starting point is permanently repaired, using Dresser couplings or solid sleeves.

Water is turned on so that, as the cleaning tool is pulled through and scrapes the deposit from the interior of the main, the water flushes the dirt ahead of the cleaning tool to the exit hole. When the cleaning tool emerges at the exit point, the line is thoroughly flushed and then is shut down long enough to permit permanent repair at the exit hole. The air is vented from the line and the line is restored to service. It is good practice to shut off the various service connections while cleaning proceeds, in order that the debris will not enter the service lines.

Pressure Method

The pressure method of cleaning includes the same preliminary steps as the drag method, namely, excavation, notification, and isolating the main. The main is then shut down, and nipples varying in length from 6 feet to 9 feet are cut out both at the entrance and exit holes.

There are two methods of entering the cleaning tool into the main. The first consists of pulling the cleaning tool into the nipple by means of a horizontal tripod braced against the nipple and using a jack, such as a coffing-hoist, to pull the machine into the nipple proper. This nipple, with the machine inside it, is then put back into the main by means of Dresser couplings or solid sleeves.

POPULATION GROWTH of cities in Southwest Section of A.W.W.A. (based on 1945 and 1950 data).

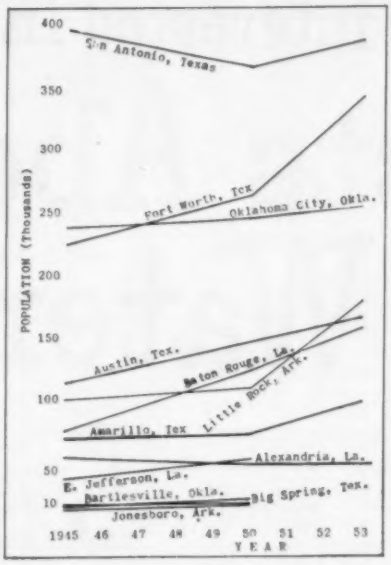


Fig. 1—Cities below 400,000 population levels.

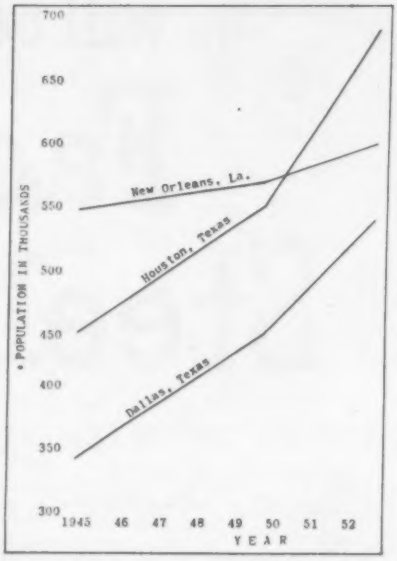


Fig. 2—Cities above 400,000 population levels.

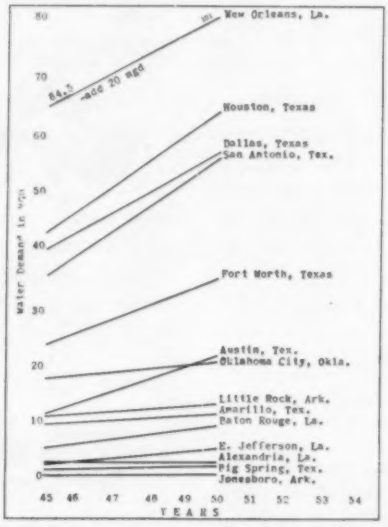


Fig. 3—Water Demand vs. Time Calculated as the product of population multiplied by per capita water consumption.

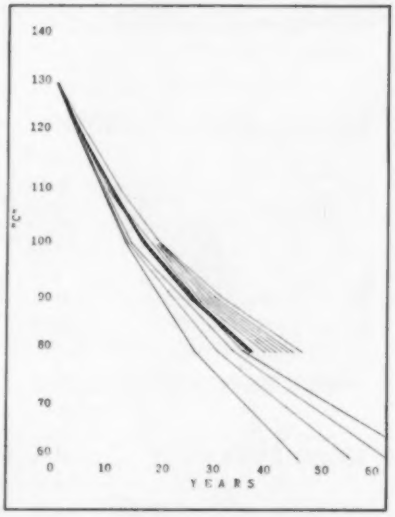


Fig. 4—"C" Value vs. Time Family of curves for various pipe sizes, based on Hazen & Williams Handbook.

The water is turned on, and the rate of travel of the cleaning tool is adjusted to between 50 and 100 feet per minute. The cleaning tool, which uses pistons to propel it, has adjustments to permit more or less water to pass through the machine and to flush the dirt ahead of it. When the cleaning tool emerges at the exit point, the line is shut down after flushing. The nipple at the exit point is again recoupled by means of Dresser couplings or solid sleeves.

Cutting the Pipe

In the past, the cutting of the water pipe has always been a time-consuming practice. Today four cuts may be made simultaneously, thus reducing the length of time the main is out of service.

Fig. 5 shows the set-up using two A. P. Smith cutters which are mounted on the pipe prior to shut-off. These employ specially designed high-cycle electric motors, and are capable of cutting any cast iron pipe in 15

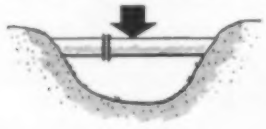
City officials, engineers, contractors will be interested in these...

Facts About Steel Water Pipe

COMPARE THE COSTS... This scale drawing compares a single 40-ft length of steel pipe with two 16-ft lengths of rigid-walled pipe of the same inside diameter. The steel pipe has thinner walls and a smaller outside diameter; weighs only about one-fifth as much per ft of length. Results: the steel pipe costs less to ship, to handle and to lay. It requires a smaller ditch, fewer bell holes, fewer joints —only 132 per mile.

TESTED FOR STRENGTH... Every length of steel pipe is hydrostatically tested at the shop in accordance with AWWA specifications—usually to double the working pressure. What's more, steel pipe can withstand from 3 to 4 times the working pressure before bursting (we refer you to the chart on the opposite page). And steel pipe safely resists waterhammer, shock loadings and surge.

BEAM STRENGTH... Steel pipe has the structural strength that is characteristic of tubular steel. It can span long washouts; is often handled in multiple lengths during installation. And steel pipe can stand up under the weight of extremely heavy cover.



RESILIENCE... Steel "gives" under stresses that would cause more rigid materials to crack or break. Steel pipe can "absorb" traffic vibration as well as shock due to explosions and earth tremors. Its resilience allows it to transmit much of the strain to the surrounding earth. This is not true of rigid-walled pipe.

LEAKPROOF JOINTS... 100 pct bottle-tight joints are a practical reality with steel pipe, whether mechanical couplings or welds are used. Water leakage is prevented; there's no contamination of the contents due to infiltration from without. These joints are quickly made, they're permanent, and they're strong.

CORROSION-RESISTANCE... Modern methods of lining steel pipe with hot-spun coal-tar enamel make it immune to corrosion and incrustation. There is no known time limit to this protection. Many tar-enameled lines have been in service for upwards of fifty years. Coal-tar enamel provides the smoothest surface obtainable, assuring high flow coefficients year after year. Coatings and wrappings protect the pipe exterior from abrasion, moisture, acids and alkalis.

SHOP FABRICATED... Remember, too, that welded steel pipe is fabricated in *permanent* shop buildings, using permanent production equipment and a permanent working force. Bad weather doesn't halt operations; freezing temperature can't effect product quality. There's no doubt of it: you get the maximum assurance of a top-notch product, delivered on time, when you use Bethlehem Steel Pipe.

WIDELY USED... Large-diameter steel pipe is the growing choice of planners of municipal and industrial water systems. Some recent users of Bethlehem Steel Pipe are: New York City, New Orleans, Philadelphia, Savannah, Reading, Cincinnati, Atlanta, Omaha, Worcester, Colorado Springs and Boston. Further proof of the superior qualities of steel pipe is its use in thousands of miles of large-diameter gas and oil lines, as well as in high-pressure penstocks throughout the world.

As this chart shows, steel pipe can withstand at least three times the calculated maximum allowable working pressure before bursting.

THEORETICAL INTERNAL PRESSURES OF STEEL PIPE

	1/4 in.			5/16 in.			3/8 in.			7/16 in.			1/2 in.		
IN-SIDE DIAM IN.	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI
18	50	445	1390	62	555	1735	75	665	2080	88	775	2430	101	890	2780
20	55	400	1250	69	500	1560	83	600	1875	97	700	2180	111	800	2500
22	61	365	1135	76	465	1420	91	550	1700	107	640	1985	122	730	2270
24	67	335	1040	83	420	1300	100	505	1560	116	585	1820	133	665	2080
30	83	270	835	104	340	1040	125	405	1250	145	475	1455	166	535	1670
36	104	225	695	128	280	870	154	340	1040	179	395	1210	204	445	1390
42	116	195	595	144	240	745	173	285	890	202	335	1040	231	380	1190
48	132	170	520	165	210	650	198	250	780	231	290	910	264	330	1040
54				186	190	580	223	225	695	260	260	810	297	295	925
60				207	170	525	248	200	625	289	235	730	330	265	835
72							306	170	520	355	195	605	405	220	695
84							346	145	450	403	170	520	460	190	595
96	The recommended minimum wall thickness is approximately the pipe diameter divided by 165. Pipe having this diameter-thickness ratio, when backfilled and properly tamped, will withstand any depth of cover. For buried pipe, the recommended minimum thicknesses are shown immediately above heavy black line.									464	145	455	524	165	520
108													*605	150	465
120													*656	135	415

*Under certain conditions stiffeners may be required to reduce deflections.

$P = \frac{t \times Ts}{r}$ P = internal pressure, psi t = thickness, in. Ts = allowable unit stress = 60% x 27,000 (yield point) = 16,000 psi

r = radius of pipe, in. Based on use of ASTM A-283, Grade B Steel, 50,000 psi min. ultimate tensile strength

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- Northwest Pumping Main, Reading, Pa.; 37,000-ft line of 30-in. and 36-in. pipe. *Booklet 408.*
- Lancaster, Pa., Water Main; 55,500-ft line of 42-in. pipe. *Booklet 431.*
- P.P.&L. Co. Flow Line, Hawley, Pa.; 8,500-ft line of 14-ft 8-in. pipe. *Booklet 432.*
- Industrial Water Main; Sparrows Point, Md.; 23,800-ft line of 96-in. pipe (please describe by name).

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minutes or less. We also use an air-operated saw. Fig. 6 illustrates these saws set up on the pipe. These particular saws have great versatility and are suitable for cutting pipe from 10-in. up to and including 60-in. diameter. These air-powered Wachs saws will cut a cast iron pipe of any thickness in a number of minutes equivalent to the diameter of the pipe.

Disposal of Waste Water

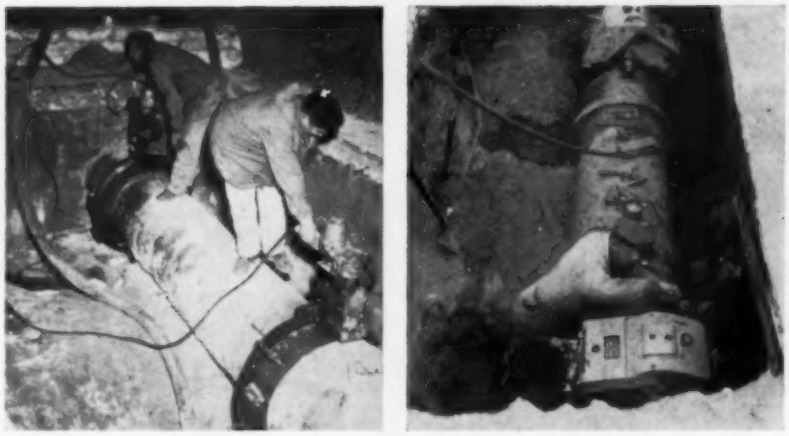
In the past it has been difficult at times to properly prepare for disposal of the quantity of wash water resulting when large diameter mains were cleaned in city streets. We have developed a technique, using line caps and small size valves, to hold to a minimum the quantity of water to be disposed of at the exit point. By this means, the total discharge from a 24-in. line, is easily handled by means of two 8-in. discharge lines.

Radio for Operations Control

Another modern practice in water main cleaning is the use of two-way radio to control the operation. Two-way radio has been so highly developed and is so successful that we wonder how jobs presently considered routine could have been handled without the use of radio in the past. Positive and instantaneous control of hydraulic grades by two-way radio during the water main cleaning has proven to be advantageous.

The combined use of the line cap and discharge lines with two-way radio control allows the line to be fully charged at all times, and the speed of the machine is regulated by the amount of opening of the discharge valves. One of the hazards, that of the possibility of collapsing the pipe, has been completely obviated; thus, the use of this method of cleaning allows water mains to be cleaned even though the head of water is exceedingly high.

In the past, large diameter machines were awkward and jacking the machine into the main was a time-consuming, laborious process. An 84-in. cleaning tool may now be jacked into a steel main, using a modern, long-stroke hydraulic jack. This operation has been reduced to a matter of minutes.



CUTTING PIPE. (Left) Fig. 5—High-cycle electric motor A. P. Smith units. (Right) Fig. 6—Air-operated Wachs saws will cut all C. I. Pipes.

DEBRIS REMOVED. Fig. 7—This quantity of material resulted from cleaning 7,000 feet of 24-in. main at Lynbrook, N. Y.

Cleaning and Lining Experience

Illustrations of the interior of water mains prior to, and after cleaning, appear in *Water & Sewage Works* Ref. and Data No., May 1954, pages R-23 to R-32.

The quantity of material removed from 7,000 feet of 24-in. cast iron main on a job at Lynbrook, Long Island, N. Y., is illustrated in Fig 7.

Where there has been deterioration of the original pipe, serious consideration must be given to rehabilitation by means of a cement-mortar pipe lining, which not only will preserve the coefficient of carrying capacity, but will stop leaks. This consideration applies to graphitic corrosion in cast iron mains as well as to the deterioration of steel mains.

It has been very general experience that, unless corrective chemical treatment is instituted, a pipeline coefficient will be reduced more rapidly after cleaning than its previous rate of reduction. This is unquestionably caused by inability to do a good job of cleaning without seriously damaging the already penetrated original interior protective coating.

Once the original paint, tar, or asphalt coating applied to new pipe at the factory has been penetrated, water comes in contact with the metal and tuberculation starts. The effect of tuberculation on carrying capacity during times of rising demands, and the resulting need for main cleaning, have been described.

Installing 10" U. S. centrifugally cast iron pipe for a water distribution system

Section of 36" cast iron outfall sewer installed on concrete piers

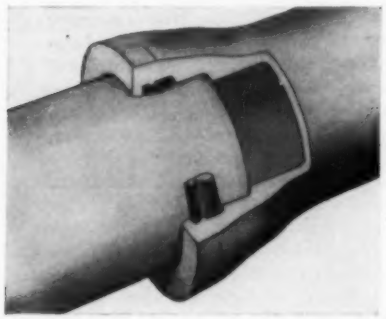
CAST IRON PIPE FOR WATER SERVICE

The practice of using cast iron pipe for water service started in Europe around 1455 and around 1820 in this country. This practice has continued down through the years and it is still the most widely used type of pipe for water distribution systems. The most desirable combination of strength and long life has made and still makes the use of cast iron pipe the most economical in the long run. Our strategically located foundries are well equipped to furnish cast iron pipe and fittings in sizes starting at 2-inch for intakes, pump stations, filtration plants, supply, feeder and distribution mains.

CAST IRON PIPE FOR SEWERAGE SERVICE

Cast iron pipe and fittings have a wide application in the sewerage field. They have three outstanding properties: 1. tight pressure type joints that prevent infiltration, 2. beam strength, compressive strength and bursting strength to withstand severe installation conditions, 3. long life and resultant low amortization charges that have been proven by years of satisfactory service.

Cast iron pipe and fittings in sizes 2-inch and up can be furnished for flow lines, pressure mains, siphons, stream crossings, outfalls, pumping stations and treatment plants.



U. S. "TYTON JOINT" PIPE

The newly developed TYTON JOINT for U. S. cast iron pipe is simple, sturdy and tight. It has only one accessory—a circular rubber gasket which is modified bulb shape in cross section. TYTON JOINT is easily made up by placing the gasket in the socket and then lubricating the inside surface of the gasket. The entering spigot is pushed past the gasket until it makes contact with the base of the socket compressing the gasket between the outer surface of the spigot and the gasket seat of the socket. The result is a joint that will remain tight at pressures in excess of test pressures required by pipe specifications.

TYPES OF PIPE AVAILABLE

Our cast iron pipe centrifugally cast in metal molds is manufactured in accordance with American Standard Specifications A21.6 or Federal Specification WW-P-421a. Pit-cast pipe is made to conform to American Standard Specifications A21.2.

Fittings (bell-and-spigot) can be furnished in accordance with American Standard Specifications A21.10 for the short-body type 3-inch to 12-inch, also A.W.W.A. Specifications C100 3-inch to 60-inch for the long-body type.

Fittings (flanged) are made to conform to American Standard Specifications Class 125 (B16.1) and Class 250 (B16b) or long-body A.W.W.A. type.

Mechanical joint for cast iron pipe and fittings is made in accordance with American Standard Specifications A21.11. Pipe and fittings can be furnished with cement lining in accordance with American Standard Specifications A21.4 or manufacturer's standard.

"Tyton Joint" pipe, roll-on joint pipe, flexible joint pipe, flanged pipe and plain end pipe are made to standard or manufacturer's specifications, whichever are applicable.

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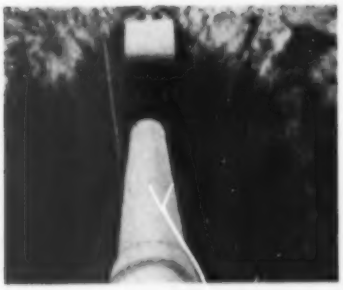
OFFICES IN ALL LARGE CITIES

Here's How TRANSITE PRESSURE PIPE with the Ring-Tite Coupling *Meets These 7 Basic Water Line Problems . . .*

IF YOU are faced with some—or all—of these 7 common water-line problems, here is information about Johns-Manville Transite® Pressure Pipe that may be of help to you...facts that tell how this modern asbestos-cement pipe is helping to solve these problems in many communities.

1. Handling costs:

Because it is light in weight and easy to handle, Transite Pressure Pipe keeps handling costs down. Loading, unloading, and all other subsequent handling operations are simplified. More footage can be hauled per truckload—reducing trucking costs—and distribution along the trench is easier and more quickly accomplished. Moreover, mechanical handling equipment is not necessary except where larger sizes are being used; the pipe sections are easily lowered into the trench with rope slings.



2. Installation costs:

Transite Pressure Pipe's light weight, easy handling and fast, accurate Ring-Tite® Coupling simplify assembly and save time every step of the way. It may be installed even under difficult weather, temperature and terrain conditions. The laying crew can install the pipe as fast as the trench is opened. This means less time on the job, appreciably lower costs. Only a few quick, sure steps are required to connect pipe with the Ring-Tite Coupling with the assurance of tight yet always flexible joints.

3. Soil corrosion:

Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

5. Underground water losses:

The Transite Ring-Tite method of assembly gives to municipal water systems the ultimate in locked-in tightness and a completed pipe line that assures the utmost in full, free flow of water under pressure. With the Ring-Tite Coupling, rubber rings are simply, speedily "smoothed" into grooves in the Transite sleeve. This simple act "spots" them easily and accurately in exact position, ready for assembly, and once in the groove, they're there to stay. The Ring-Tite Coupling is designed to stop automatically in the correct position to form a tight yet flexible seal.

6. Vibration and stresses:

Not only is the Ring-Tite Coupling designed to stop in the correct position for tightness; it also stops in just the right position for separation of pipe ends within the joint. This means that the coupling automatically provides for expansion, possesses the flexibility to relieve line stresses in service. The flexible joints effectively absorb the vibration of heavy traffic, especially important where pipe is laid under busy highways or near railroad and street car tracks. Deflections up to 5° at each joint permit laying pipe around curves without special fittings.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

. . . the advantages of a complete, nationwide TRANSITE PIPE ORGANIZATION. The facilities of this organization include more than 250 field representatives with headquarters in 58 cities. It also comprises a staff of competent installation instructors who explain recommended installation practices to pipe-laying crews.

This J-M service is an important factor in helping to assure the installation economies as well as the long-term *overall* economies that go with Transite Pressure Pipe. The work of this field organization is a vital part of the helpful Transite Pipe service which J-M offers the water works industry.

DIMENSIONS AND APPROXIMATE WEIGHTS OF TRANSITE PRESSURE PIPE

Transite Pressure Pipe is available in seven sizes from 4" through 16" and in three working classes—100, 150 and 200.

Class (maximum recommended working pressure, psi)	Equivalent head, feet of water	Nominal inside diameter, in.						
		4	6	8	10	12	14	16
		Pounds per linear foot including Ring-Tite Coupling						
100	231	6.3	10.6	15.8	21.8	29.7	38.9	48.8
150	346	7.6	13.0	19.9	32.0	43.8	58.5	73.0
200	462	9.3	15.4	23.9	37.2	51.7	69.0	89.2

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SMS VALVES FOR DEPENDABLE ECONOMICAL SERVICE

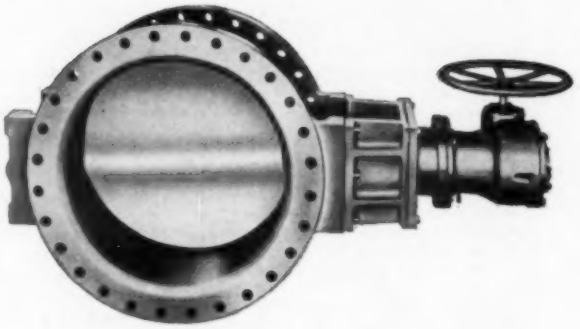
R-S AND SMS BUTTERFLY VALVES

MORE COMPACT and lighter in weight than most types. They permit concise layouts with direct savings in construction and in-place costs. Valves are made in all materials that can be cast or welded. Metal-seated valves can be built to operate over any range of temperature, either sub-zero or elevated. Babbitt or rubber seats meet a wide range of pressure and closure conditions. Rubber-seated butterfly valves are drop tight at 125 psig through a temperature range from plus 200°F to minus 20°F.

COMPLETE CONTROL in all positions of normal regulating range. The valve can be equipped with positioner to simulate a straight linear or semi-log characteristic.

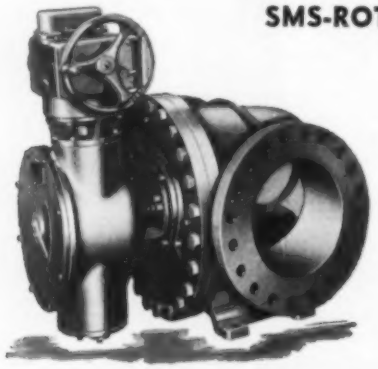
ALL TYPES of operators are available. Closure time can be furnished from 1 second to 10 minutes or more to meet operation needs.

MINIMUM PRESSURE DROP SAVES POWER. In open position the streamlined valve disc simulates a Venturi action. Pressure drop is less than in many other valve types resulting in substantial savings in pumping power.



A 50# rubber-seated valve with totally-enclosed manual operator. R-S rubber-seated valves have a tough, resilient rubber seat which positively seals the disk periphery and shaft bosses.

SMS-ROTOVALVES FOR RUGGED SERVICE . . .



THE ROTOVALVES' full line opening offers no more resistance than a straight piece of pipe of the same diameter. Less resistance means less head loss for the lowest pumping costs obtainable. SMS-Rotovalves are the proven answer to many control problems. The principle of hydraulic imbalance assists closing for faster, easier operation. One Rotovalve can often replace two or more conventional valves for faster, more positive closure and control of water hammer.

WEAR FACTOR is negligible with Rotovalves. In operation the conical plug first lifts, then rotates, finally reseats in either open or closed position. This action ensures *tight, positive seating* throughout valve life by avoiding wear and abrasion at the valve seats.

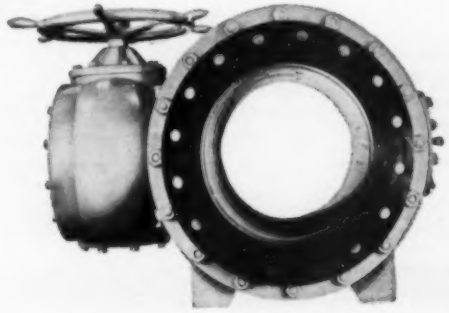
SMS BALL VALVES GIVE STRAIGHT-THROUGH FLOW

BALL VALVES are similar in flow characteristics to SMS-Rotovalves. They do not seat in the open position, and have slightly greater head loss than Rotovalves.

TIGHT CLOSURE is assured by the wedging action of the metal-to-metal seats.

EASE OF OPERATION results from tremendous leverage and the fact that flow velocity tends to ease closure.

SMS BALL VALVES provide across the board economy—lower first-cost, lower pumping costs and extended line and valve life.



Selecting Valves for Water Service

by LESLIE PAUL

Supervising Mechanical & Electrical Engineer, East Bay Municipal Utility District, Oakland, Calif.

IN water works systems located on the banks of large rivers or the shores of lakes where the terrain is flat and where water can be distributed through one large, well developed network in one pressure zone, the application of valves and other mechanical devices has evolved into a fairly standardized and comparatively simple pattern. The East Bay Municipal Utility District is not so fortunate, because its 213 sq mile service area, in which it furnishes 129 mgd to 1,000,000 people, varies in elevation from sea level to 1,552 ft. The bulk of the water must be transmitted from the main catchment area in 65-in. and 68-in. pipelines for a distance of approximately 95 miles. The service area is bisected by a main ridge of hills, with branch spurs and steep canyons projecting into the sides, and several other hill systems are also present.

Water works valves can be classified in several ways. One method would be to differentiate between isolating and operating valves. An isolating valve is a device for blocking off a section of pipe in a grid system or protecting operating valves or pumping units, so that inspection or maintenance can be carried out without removing them from the line. An operating valve is one that is used frequently for starting, stopping, or regulating flow or for regulating pressure.

In this paper, valves are divided into seven principal categories: sluice gate, needle, check, butterfly, plug, globe, and gate. There are other types of valves — such as shear gates, mud valves, tide or flap valves, and hydrant valves—which are designed for special applications where selection of type is not a matter of judgment.

Sluice Gates

Sluice gates are used principally on inlet or outlet pipes entering reservoirs, on the side openings of reservoir control towers, and on flume and canal systems where a throttling or shutoff device immersed in the water must take pressure on one side of the leaf only, so that pressure tends to seat the gate.

Some sluice gates are installed so that pressure forces the leaf away from the seat, tight shut-off depending on the jamming of the leaf against the seat by the wedges.

Sluice gates are obtainable with both rising and nonrising stems, but the use of the latter should be discouraged. The threaded section of a rising stem, being out of the water, serves as a position indicator and can be made of steel. It can be lubricated and no torsional stresses are transmitted to the disc and guides. In the nonrising-stem type, the working parts are immersed in water and cannot be lubricated. The operating nut, rigidly fastened to the disc, and the operating stem must be made of bronze. In operating the gate, the torsional stresses applied to the stem are transferred to the disc and guides. If a sluice gate of this pattern is operated infrequently, the threads of the stem and nut tend to freeze together and the extra torsion necessary to loosen them may break the stem at its point of greatest weakness, the inner end of the threaded section.

Sluice gates manufactured by old, established firms are practical, quality products, standardized to cover a wide range of sizes and pressures. The structural features are well designed and proportioned.

A sluice gate assembly is no stronger than its weakest part. Very often it is the bolting that shows up badly, especially where conditions for setting up galvanic couples are favorable. These may exist where a sluice gate frame is bolted directly to a concrete wall, especially if the bolts are in contact with reinforcing steel. In that event, the steel part imbedded in the concrete will tend to destroy electrolytically the part not so imbedded, the nut deteriorating first. Bolts in contact with bronze parts should be of silicon

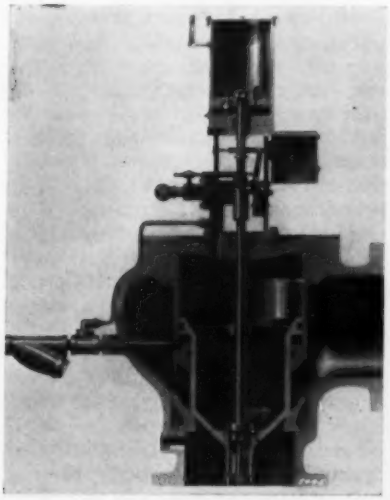


Fig. 1. NEEDLE type surge supressor.

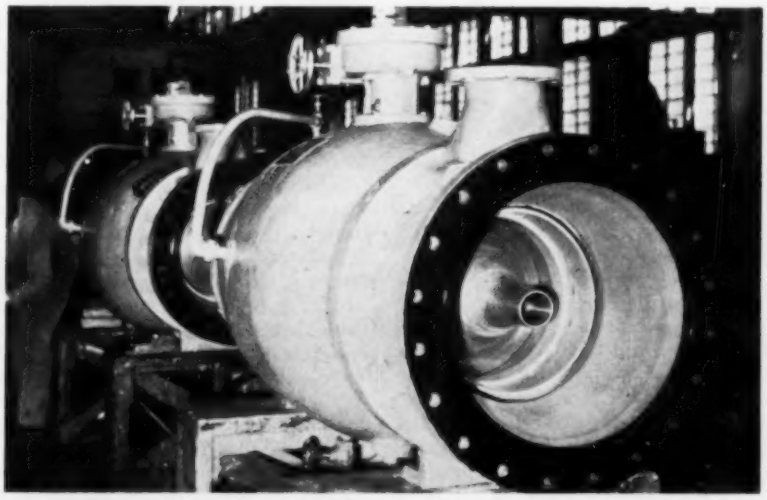


Fig. 2. LARNER-JOHNSON needle type valve (usually controlled hydraulically).

bronze or equal, to prevent such corrosion. The bolting should be as durable as the castings, and under no circumstances should a steel nut be used on a bronze bolt, or a brass or bronze nut on a steel bolt.

Various kinds of copper alloys are being sold as bronzes. Some of these are not bronzes but different degrees of high-zinc brasses, although insiduously, they all look alike. The word "bronze" should not be used indiscriminately to cover all metals with a yellow color. It is important that the composition of bronzes be described and specified within given limits, in accordance with ASTM or other recognized standards rather than by a manufacturer's trade name. The manufacturer should be willing and able to comply with ASTM or similar requirements.

Valve manufacturers favor certain so-called bronzes for reasons of machinability, cost, and tradition. Many are not bronzes but high-strength, leaded, yellow brasses with high zinc content and thus are susceptible to dezincification in some waters. Hence, such alloys should be avoided in writing valve specifications if better ones are available.

When sluice gates are infrequently operated, and especially when they are not readily accessible, the gate and guide tongues and grooves should be covered or lined with low-zinc bronze, stainless steel, or Monel metal. All sliding, rubbing, or wedging surfaces should be bronze to bronze, stainless steel to stainless steel, or Monel metal to Monel metal.

The safety factor is important in selecting a sluice gate frame for use in waters that cause graphitization, especially if the commonly employed ASTM A126, Class B, cast iron is to be the frame material. A safety factor of five should be an absolute minimum for cast-iron parts subjected to predictable stresses. Sluice gate frames can be flexed very easily, so that bolting and wedging action may produce higher stresses than anticipated if the original installation results in improper frame warping. For guide sections and bolting subjected to wedging action, the safety factor should be much higher, probably not less than fifteen.

The most satisfactory sluice gate installations are those which are flanged and bolted to a flanged wall thimble embedded in the concrete structure. This arrangement makes installation easy, eliminates warping of the frame, and permits removal of the gate without disturbance to the masonry. Gates that are bolted to the masonry are easily warped, as masonry surfaces can never be built true and flat like a machined metal surface, and water leakage between the frame and the masonry can erode away enough concrete to make the installation ineffective as a water stop.

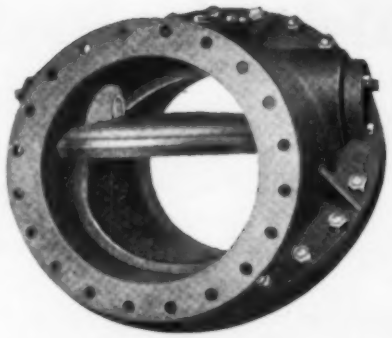


Fig. 3. TILTING-DISC check valve.

Needle Valves

Needle valves (Figs. 1 and 2), in the smaller sizes, are used principally for fine regulation of flow through pilot control mechanisms, because a large movement of the hand wheel results in only a slight movement of the needle with relation to the valve seat. These small, hand-operated valves resemble the globe type, except that, instead of a disc, a streamlined or tapered plug fits into a ground seat. The fluid flows around the plug and through the seat.

In the larger sizes, needle valves have a variety of applications. An important one is the throttling and control of free discharge from reservoirs and pipelines. Medium-size valves are operated mechanically in various ways, but the large sizes are usually controlled hydraulically by the internal-differential method. Because the fluid must flow longitudinally around the outside of the plug, the hydraulic-power elements and the working parts are buried within the body of the valve. A disadvantage of this arrangement is the comparatively high weight of the valve for any given size. Means of getting around this difficulty have received much study, especially by the US Bureau of Reclamation and some of the big power companies that use these valves in very large sizes. The Bureau of Reclamation has improved on the internal-differential valve with what it calls a tube valve, but needle valve design seems to be in a continuing state of modification. (The East Bay system has 22 needle valves, ranging in size from 6 in. to 72 in., all purchased from the same manufacturer.)

The cylinder gate represents an interesting attempt to overcome one of the disadvantages of the needle valve by making the working parts accessible on the outside of the valve. The plug or needle remains stationary, with the point upstream, and a cylinder is drawn back in the upstream direction, which uncovers four ports, causing wide-angle discharge. Where wide-angle discharge is undesirable, a hood can be built to confine the normal expansion of the jet. This valve is capable of discharging a greater quantity of water than conventional needle valves of the same nominal diameter.

The needle valve is sometimes used to regulate flow or pressure in a pipeline, but, when repairs are necessary, the valve body must be removed from the line. (Two of the East Bay needle valves are 6-in. pressure regulators.)

The sleeve valve is another attempt to avoid some of the difficulties of the needle type installed in pipelines. For maintenance or repair, the body and working parts of the sleeve valve can be lifted out of the line without breaking the flange connections to it.

Needle valves may be used as check valves on pump discharges where controlled speed of closing is essential or where the flow must be throttled to a given rate. (East Bay employs one 18-in. and three 24-in. conventional needle valves and three 30-in. sleeve valves for this purpose.)

Check Valves

In spite of claims by manufacturers and their sales representatives, there is no such thing as a check valve that "eliminates water hammer." The effect of water hammer may be mitigated by the speed of operation of a certain type of valve under a given set of conditions, but no valve ever nullifies it entirely. Furthermore, a check valve that works well under the conditions imposed by one installation may not work well in another installation. When the velocity of a column of water moving in a pipe is changed, alternating waves of high and low pressure will travel back and forth in the line. Although the check valve may aid in reducing the effect of surge on the pipe system, it may through its own action, create a worse wave system that can be damaging to the line. The primary purpose of a check valve is to prevent reversal of flow. Any of the valve types common in the water works industry can be adapted for this purpose; but, under differing hydraulic conditions, one type may be better than the others.

Of the many check valves on the market, the most familiar is the swing check (Fig. 3). It can be single hinged, lever and weight loaded or spring loaded. With either of the last two designs, the loss of head will be increased, because the leaf will be

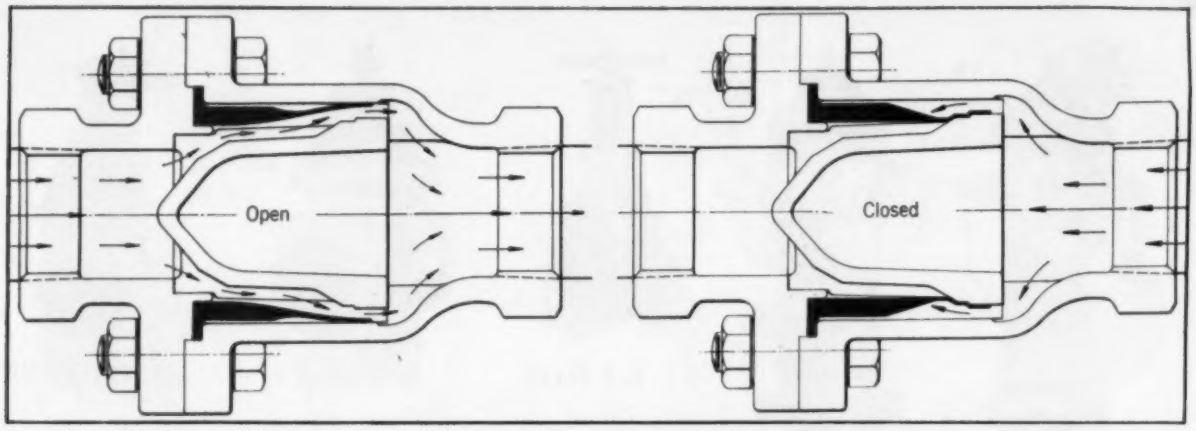


Fig. 4. BASKET type check valve (a check valve that closes very rapidly).

forced down into the stream and the effort necessary to force the valve open will be greater. If, in order to reduce loss of head, a larger valve is selected for a given flow, the velocity will be less and the valve will not open as far. Conversely, if, in order to get the valve open, a smaller valve is chosen, the velocity will be higher and the loss of head will be greater.

If the hinge pins are made of yellow brass, the flap will eventually drop off, because dezincification and friction will combine to ruin the valve.

The great disadvantage of this type of valve is lack of control over the time of closing. Swing checks are successfully used in numerous manually operated pumping plants where the pump is started against closed gate valves. In such instances, the only hazard is power failure which may cause the check valves to close, with resulting shock. Swing check valves also work satisfactorily in pumping plants connected to well developed grid systems, provided only one pump is operated. If a second pump is utilized in parallel with the first, the stopping of one may cause a damaging metal-to-metal slam on its check valve, but without propagating a water hammer wave.

Some engineers do not trust the newer types of check valves, preferring to rely on the old-fashioned swing check. When they encounter water hammer troubles, they add air domes, requiring periodic air replenishment, or surge pipes, relief valves, or other auxiliary devices that take up valuable space and demand extra maintenance effort. Such arrangements may solve specific problems, but they are often unnecessary if one piece of well chosen equipment will do a comparable job.

In transmission pumping plant lines, where the time of acceleration or deceleration of the water column can be measured, a very fine type of check valve to use is a hydraulically operated, nonlubricated plug valve. In shutting down a plant of this sort, the valve can be so controlled as to close completely at the instant that the velocity of the water column becomes zero, while, in starting the plant, the speed of opening can be slowed down, so that the compression wave which builds up at the pump when the column is accelerating is reduced to a minimum.

The hydraulically operated internal-differential needle valve previously mentioned can serve a triple purpose as a throttling, check, and pump control valve. The so-called sleeve valve, which is a modified needle type also described earlier, is often used for this purpose.

If a plug or needle valve is used on a pumping installation where the discharge line is very short, it may not be possible to close the valve before the flow of the column reverses direction. In this situation, the valve must be closed very slowly, allowing the pumps to rotate in reverse. There are some pumping plants which operate in this manner. Such valves should not be used if there is a possibility that the shaft sleeves on the pump will unscrew during reverse rotation.

In a pumping installation where the characteristics of the distribution system require a check valve that closes very rapidly, the basket type, with an expanding elastic "Hycar"* sleeve, does an excellent job (Fig. 4). These valves are marketed in sizes up to 12 in. Those used at East Bay are plastic lined on the inside. One advantage of this valve is lack of direct contact between different metals.

There are 65 of these checks in the East Bay system.

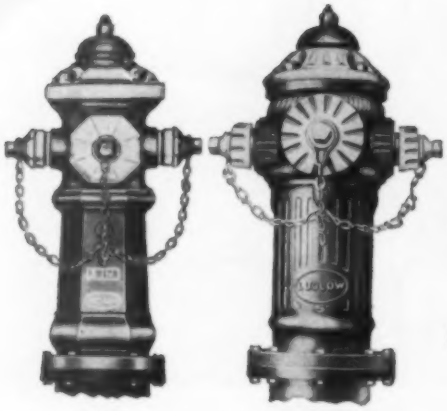
In an automatic pumping installation where the pumps must be started and stopped against closed valves with a regulated speed of opening and shutting, East Bay has successfully utilized a solenoid-actuated, diaphragm-operated, globe pattern valve with the controls built into the assembly (Fig. 5). Internal parts are bronze and the free-floating disc that is pressed up against the head by line pressure has a hollow, stainless-steel stem which slides on a spindle guide so that, in the event of power failure, the disc drops to the closed position almost at the instant that the water column attains zero velocity and before it can reverse. In that respect, this valve is superior to the spring-loaded or lever-and-weight swing check and the loss of head is no greater. (There are 36 electric check valves, sizes 4-16 in., in the East Bay system.)

In situations where swing checks used as dividing valves for combination gravity and transmission pumping to a reservoir give trouble, slow-closing, diaphragm-operated, globe checks have proved to be very successful shockless substitutes (Fig. 6).

The first automatic pump control valves used at East Bay, in the late 1930's, were gates. At that time it was suggested to some gate valve manufacturers that, because there was a trend toward automatic pump control, it might be well for them to market an assembled, hydraulically operated, solenoid-controlled gate. The suggestion was rejected on the grounds that the factories were set up for quantity production of gate valves and were not organized to handle economically a specialty that did not promise a steady volume of consumer demand.

This refusal led to a search for substitutes, and the need for a self-contained automatic pump control valve has been satisfied by the makers of other types of valves, who could start fresh, without the handicaps of tradition. The first pump control gate

*A trade name of B. F. Goodrich Chemical Co., Cleveland, Ohio.



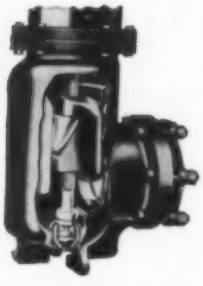
LIST 90-0

LIST 75-0

O.S. & Y VALVE

NRS VALVE

GEARED VALVE



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A.W.W.A. VALVES AND HYDRANTS: with several types of each to choose from, with a complete line of valve ends in every size required and backed by our combined engineering, manufacturing and application resources.

LARGE AND SPECIAL VALVES FOR LOW AND HIGH PRESSURE SERVICE: up to 72", fabricated with the most modern foundry and machine shop equipment, recently expanded.

SQUARE BOTTOM VALVES: from 4 to 48", designed and built to stand up under the severe conditions of automatic operation, throttling and constant opening and closing.

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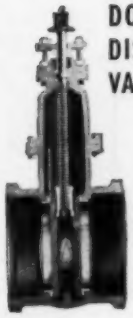
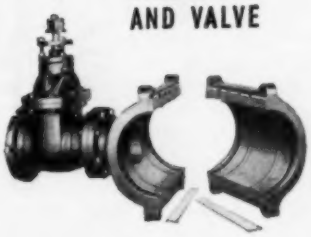
Since 1861 **THE LUDLOW VALVE MANUFACTURING CO.** *Troy, N. Y.*

SQUARE BOTTOM VALVE



DOUBLE DISC VALVE



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MOTOR OPERATED VALVE

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CHECK VALVES: insure against slam on pump shutdowns. Clearway-quiet closing, single disc. Sizes up to 30" with or without lever arm and spring.

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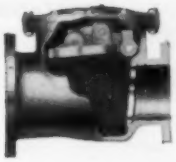
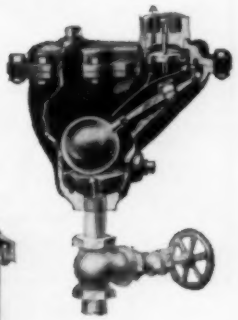


CHECK VALVE



AIR VALVE

FIRE HYDRANT

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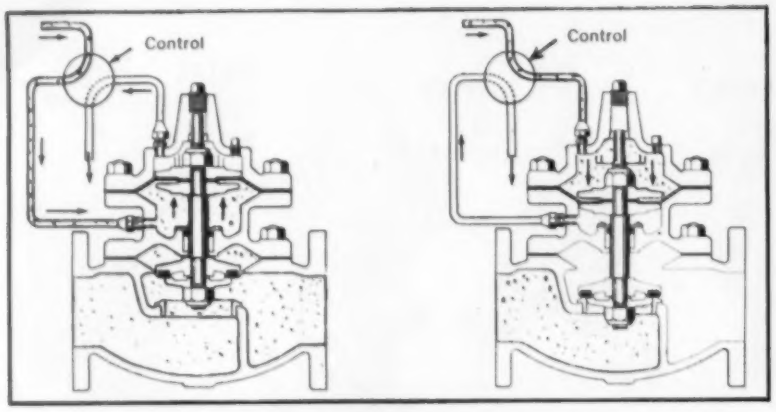

Fig. 5. SOLENOID-CONTROLLED check valve (often used with automatically operated pumps).

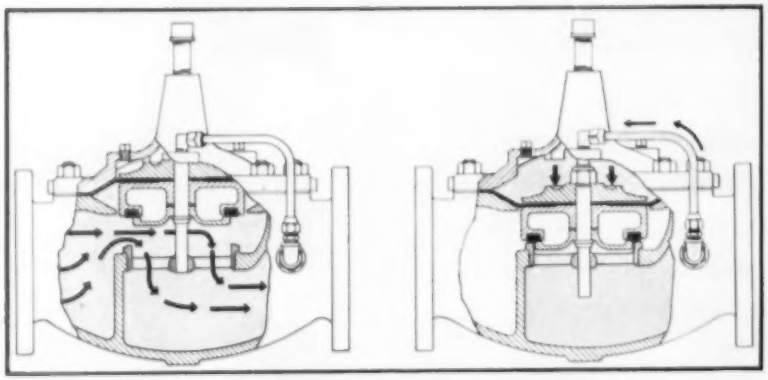

Fig. 6. SLOW-CLOSING globe type check valve (sometimes a substitute for swing checks).

valves at East Bay wore out in 1-5 years, depending on how often they were operated, whereas pump control valves of other types have continued in service or have been moved to different plants for further service with practically no maintenance work required on the valve proper.

Butterfly Valves

The butterfly valve, in 4–72-in. sizes, is coming into increasing use in general water works practice, while, in special installations, sizes up to 14 ft are employed. This valve possesses a great advantage in having only one moving part. As now built, butterfly valves can compete in price with the best-quality gate valves, provide tight shutoff, require minimum maintenance, and have a long service life.

For bubble tight shut-off at pressures less than 125 psi, the synthetic or gum rubber lined or seated valve is available in three types as a staple market item. One type (Fig. 7) in which the disc closes at a 90 degree angle to the stream flow has a thick gum rubber seat mechanically fastened to the valve body by stainless steel plates and screws. In another type the disc closes at an angle to the body and a rubber liner is cemented or vulcanized to the entire inner surface of the valve body, the liner turning out at the water way flanges to form gaskets at the ends of the valve. A third type, (Fig. 8), which has been developed on the Pacific Coast within the last two years, has a disc which is rubber mounted at the perimeter and closes against a stainless steel ring embedded in the body. The disc is offset from the centerline of the stub shafts which, in turn are offset from the centerline of the valve body so that the disc turns up to the seat eccentrically. This latter valve has several advantages over the conventional butterfly; the shaft does not penetrate the seats and the rubber seat is easily replaceable on the disc without disassembling the whole valve. East Bay has 27 of these valves in the system ranging in size from 6 to 24 inch. Since it is at least the equal of the conventional butterfly types covered by the A.W.W.A. Specifications, the specifications should be revised to include this new type of butterfly. All three types of rubber seated butterfly valve are meeting with increasing favor in filter plant installations.

For pressures higher than 125 psi, a variety of metal-to-metal seat arrangements, both adjustable and fixed, can be obtained with very low rates of leakage. Butterfly valves can be used wherever any other type is employed in water works practice, except in pipes requiring a full-size round opening through the valves to permit the passage of lining or scraping equipment.

Butterfly valves may be manually or power driven. The low power requirements make it easy to adapt electric-motor or pneumatic or hydraulic drives of either the diaphragm or piston type to these valves. Automatic operation can be full open or shut, or infinite position between these two. Bodies and discs may be of cast iron or cast steel, shafts of stainless steel or Monel, bushings of bronze, vanes with hard chrome edges, and body seats of monel metal, Babbitt metal, bronze or stainless steel depending on the manufacturer and the use to which the valve is to be put.

Although a longitudinal section through a butterfly valve may make it appear symmetrically balanced, it actually is not. Of the great variety of valves used in water works, the service application of the butterfly requires the closest scrutiny by both the purchaser and the salesman. Overeagerness on the part of the latter to sell a butterfly valve with a light-weight shaft for a service application requiring a heavier one has resulted in incidents that have created unjustified prejudice against a very fine water works device.

Three basic service applications may be classified as follows: [1] a closed system with a limited pressure drop and limited flow, such as at the effluent valve from a filter bed; [2] limited free discharge, such as in a main break downstream from the valve or pump discharge to a dry system; and [3] full free discharge, such as at a valve mounted on the downstream face of a dam. In each of these applications, the magnitude of the seating, bearing friction, hydrostatic, and hydrodynamic or flow torques is different. The counter-torque that must be applied to the shaft in each instance determines the size of the shaft.

Under some conditions of pressure and flow, the shaft and disc would have to be designed too thick to be practical, and it would be better to use the disc-arm valve, a modification of the butterfly in which the disc is pulled into the open position from the outer perimeter by a tension bar linkage acting through a stuffing box on

the top of the valve (Fig. 9).

There are 26 butterfly valves in the East Bay transmission system—two 42-in. and two 72-in. isolating valves that protect free-discharge needle valves in the downstream face of Pardee Dam; two 72-in. isolating valves upstream from the 10,000-hp Pardee turbines; nine 60-in. turnout valves, for isolating an 8,000-hp and a 5,400-hp transmission pumping plant (one of these valves has a shaft heavy enough to permit closing in the stream); three 48-in. isolating valves on the suction lines of three large pumps; and four 36-in. electrically operated and four 42-in. hydraulically operated butterflies, each linked to an 18-in. needle valve, at eight automatic, synchronous stop and relief valve stations established at 20-mile intervals in the 65-in. and 68-in. transmission lines (the discs and shafting of the butterflies are heavy enough for the valves to be closed in the stream). A break in the line downstream from one of these stations would cause an increase in flow rate, and the venturi effect through the restricted opening of the valve would create increased differential in the float chambers of a mercury U-tube tripping a triggering device that would start the butterfly closing at the same time that the needle valve started opening.

Fig. 7. RUBBER-SEATED butterfly valve. For absolutely tight shutoff at pressures of less than 125 psi.

Although butterflies are often used as free-discharge valves, other types on the market would, more often than not, be better suited for this purpose. Anyone who has ever been near a large butterfly valve discharging freely into a downstream pipe section under high head while operating through the critical point in its opening or closing stroke will remember a terrifying experience, but, under normal conditions in a pipeline, these valves are silent, efficient, and easily controlled.

There are 67 butterfly valves in the East Bay distribution system, 28 with metal seats being designed for direct burial in the ground; 1—54 in., 9—48 in., 5—42 in., 7—36 in., 2—30 in., 3—24 in., and 1—20 in. Miscellaneous filter and pumping plants and reservoir installations absorb 39 rubber seated butterflies; 15—20 in., 8—16 in., 4—12 in., 6—8 in., and 4—6 in. All of these valves are designed for closure by one man under total pipeline break conditions down stream from the valve. The 48 and the 42 inch valves are installed consecutively at intervals in long transmission mains in the distribution system; while some of the 36 and 30 inch butterflies are interspersed with gate valves in such a way that, in the event of a total line break, downstream from a gate, where difficulty would be experienced in closing the gate, the butterfly could be easily closed, either totally or partially to reduce the velocity and pressure acting on the gate.

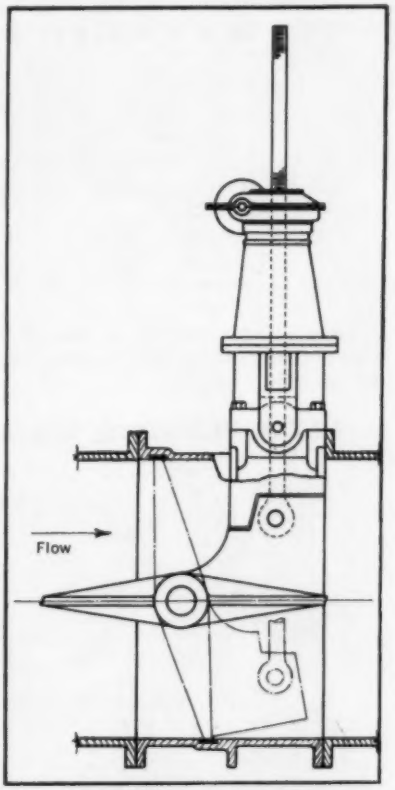

Fig. 9. DISC-ARM pivot valve. This type is a modification of the butterfly valve.

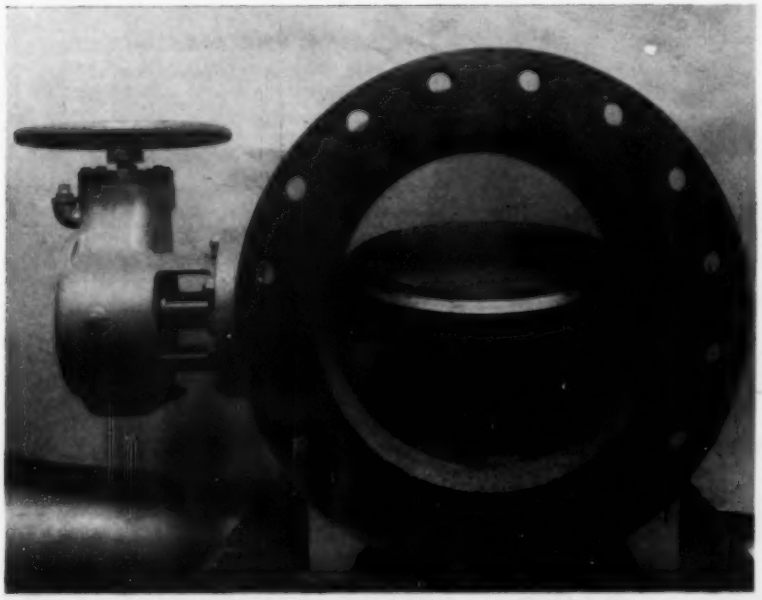

Fig. 8—A THIRD type of butterfly valve. The disc is rubber mounted at the perimeter and turns up to seat eccentrically

East Bay has a 36 inch cast steel butterfly which replaced a gate valve worn out in about three months of intermittent throttling service. In a 36-inch line parallel to the line in which this valve is installed the author watched four of our huskiest men take 2½ hours to close a 30 inch gate valve (with bypass, tracks, rollers and scrapers). Then one man, with ease and in a few minutes turned the wheel of the 36-inch butterfly and set the desired rate of flow on the venturi meter. Hydraulic conditions on both valves were approximately the same. This 36-inch butterfly throttles efficiently and with hardly any noise.

Butterfly valves are successfully replacing sluice gates on reservoir outlet towers. Rubber seated butterflies are used where they will always be immersed in the water and protected from sun light and heat, while

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

(Subsidiary of Walworth)

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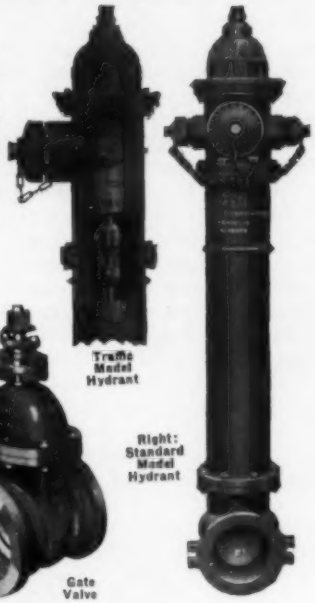

Traffic Model Hydrant

Right: Standard Model Hydrant

Gate Valve

M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc parallel seat, or solid wedge, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure and High Pressure Valves and Square Bottom Valves are an established part of the M & H line.

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Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

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Hydraulic Gate Valve

Low Pressure Gate Valve Non-Rising Stem

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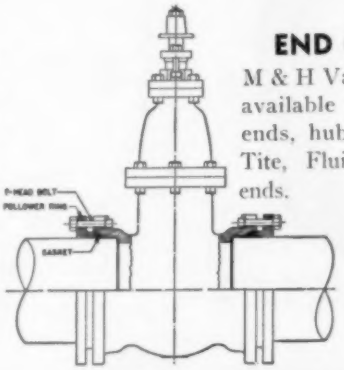
M & H Valves and Hydrants are available with Mechanical Joint ends, hub ends, flanged, Ring-Tite, Fluid-Tite and Universal ends.



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M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve

Spring Check Valve

Indicator Post

M & H PRODUCTS INCLUDE:

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CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	R & S FITTINGS	FLANGE AND FLARE FITTINGS
CUTTING-IN VALVES	& SLEEVES	CUTTING-IN TEES

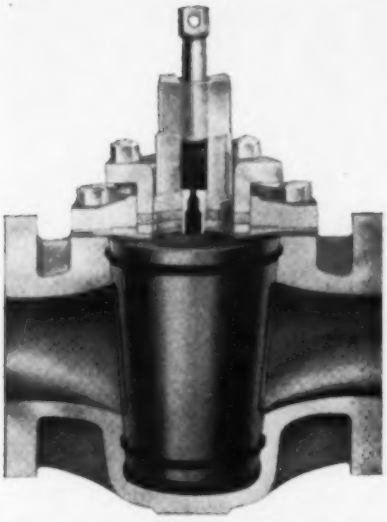

Fig. 10. LUBRICATED plug valve. Successfully used as isolating valves in grid systems and pumping installations.

metal seated valves are being used above the constant immersion line.

The butterfly valve has one great advantage over other types in its short face-to-face installation length. This, together with the fact that, for sizes 30 in. and greater, a butterfly valve can be purchased for less than any other kind designed and equipped for comparable water works duty, is a good argument for the wider use of butterfly valves in large distribution pipelines.

Automatic Stop Valves

It has been suggested by some civil defense authorities that automatic stop valves be installed on reservoirs in congested areas to conserve storage in the event of a disaster in which the distribution system suffered serious damage. Correspondence and discussions with many water works men have led the author to believe that this arrangement would be highly expensive and impractical for a distribution system. It might even do more harm than good in certain types of disaster where water may be badly needed to put out a fire.

Plug Valves

The plug type valve with one moving part in the valve proper is familiar to every water works man, as it is used in every water service which has a service cock tapped into the main and a curb or corporation cock at the point of service, commonly upstream and just ahead of the meter, if any Cocks that isolate gages and other forms of instrumentation utilized in the water industry are another application for the plug valve. Still another is the three- or four-way cock used to control pressure on hydraulic cylinders that operate larger valves. The plug valves mentioned are of the dry type and are made of brass when used in water service.

An all-iron lubricated plug valve is receiving increasing attention from water works operators. It can be obtained with a plug opening area equal to 90 per cent of the nominal area of the valve in sizes up to 16 in. In the venturi pattern, it is furnished in nominal sizes up to 30 in. A 30-in. venturi pattern valve would have a plug opening area approximately equal to that of a circle of 19-in. radius; a 24-in. valve, 15-in. radius; and a 20-in. valve, 13-in. radius. Thus, the venturi pattern plug valve would have approximately the same opening area as a butterfly valve of the same nominal size and pressure rating.

The lubricated plug type (Fig. 10) is successfully used by some plants as an isolating valve in grid systems and pumping installations. East Bay employs about 75 such valves, in various sizes, for this purpose in pumping plants and other automatic installations, and about fifteen, in the 16-, 20-, and 24-in. size, as turnout valves from transmission lines. A 24-in. and a 30-in. plug are used as remote supervisory control water-dispatching valves, electrically operated and controlled through leased telephone lines from a central dispatching point 12 miles away. Another 30-in. plug is used as a float-controlled, hydraulically operated altitude valve. A 16-in., 90 per cent open, manually operated plug is doing a fine job as a throttling valve under very severe conditions.

This valve has been preceded in service by a 16-inch gate valve which wore out in three months and by a 16-inch square bottom gate which wore out in less than a year. After over four years the lubricated plug was removed for inspection and found to be in excellent condition with only a few small cavitation pits on the

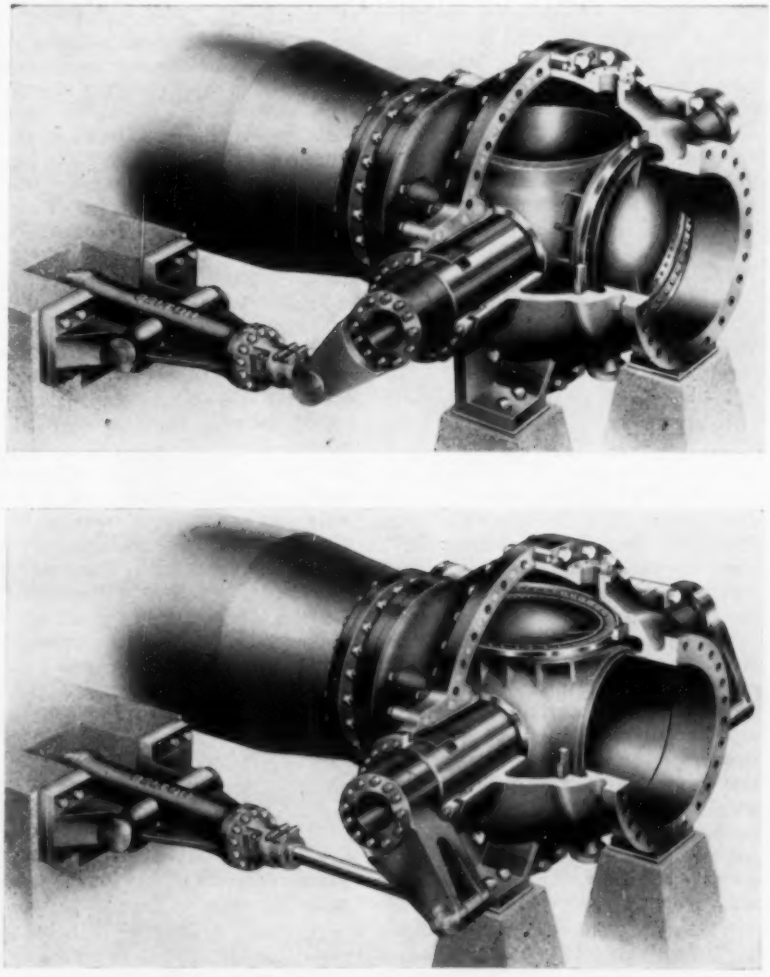

Fig. 11. NONLUBRICATED spherical plug valve. Top—closed; bottom—open.

down stream side of the plug. The valve was reinstalled in service in another location without any repairs where it has given good service for another 4½ years.

Four-way lubricated plug valves are excellent for filter plant control table manifolds, and East Bay has two filter plants so equipped.

The lubricated plug valve installations at East Bay have been very successful. The main difficulty has been in getting operating personnel accustomed to using new equipment; once they become familiar with these valves and note their ease of operation, however, they want more of them. It is important to remember that, if this type of valve works hard or has a tendency to stick, the stuffing box on the top should be tightened—not loosened as with a gate valve—so that an application of grease through the pressure fitting will jack the plug loose. On one occasion, the 30-in. dispatching valve previously referred to was found to be stuck, but it was easily freed by applying grease and operating it manually. Operation from time to time through a partial stroke has prevented further trouble. Although some water works men have expressed fear that the use of these valves would allow grease to escape into the distribution system, no consumer complaint on this subject has been brought to the author's attention during the 16-year period in which East Bay has employed this type of valve.

The nonlubricated, full-open, conical type of plug valve is another very fine water works valve, which allows smooth, unrestricted flow when fully open. This valve is mechanically jacked up from, or down to, the seat in either the fully open or the fully closed position. Even in the largest sizes, it can be manually operated easily and quickly by one man. (In fact, men accustomed to operating gate valves by sheer brute strength have been known to damage such a plug severely, because they could not bring themselves to believe that a valve, especially one of large size, could be closed so speedily without requiring a crew of laborers to lay their weight against a capstan bar.) The valve can also be operated by water or oil hydraulic power, compressed air, or electric motor. The workmanship in these valves is first class, and a wide choice of high-grade nonferrous metals for mounting in the wearing and seating parts is available, Monel metal being a favorite.

This type of valve offers the following advantages: [1] positive control of valve timing; [2] free, unobstructed flow, with the head loss equivalent to that in a straight piece of pipe of equal length and diameter; [3] no contact between the valve seat and the direct flow of the fluid; [4] operation with full unbalanced pressure, thus eliminating necessity for bypasses; and [5] complete enclosure and full lubrication of all working parts. One of five such valves at East Bay, a 42-in. valve on the tunnel outlet at the upstream end of a 68-in. pipeline 90 miles long, is hydraulically operated through a closed-system air and oil accumulator set. In the event of a break downstream from the valve, the increased flow through a venturi meter actuates a trip mechanism and governing device, which, in turn, automatically causes the valve to close at a fixed speed, regardless of the temperature, the viscosity of the oil, or the magnitude of the break.

A 36- and a 30-in. motor-operated valve are used as remote supervisory control rate-setting valves. Two 30-in. valves are employed at strategic locations in a 48-in. transmission line for rapid one-man operation in emergency shutdowns. These valves supplement three of the usual isolating gate valves, which take much more power and time to operate than the plug type. A metropolitan water system with an average consumption about four times as large as East Bay's uses many of these valves in large transmission lines, either in the manner described or as substitutes for the traditional gate valves, but spaced at greater intervals.

The ball valve, a full round opening, nonlubricated plug type, seems to have all of the advantages of other large plug valves and is meeting favor wherever it is used. Mechanical jacking of the plug from the seat before turning is cleverly avoided by setting the plug slightly eccentrically on the shaft, so that the plug seat and the body seat match, with metal-to-metal contact, when the valve is closed. A 16-in. ball valve used for very severe throttling service in one of East Bay's remote supervisory rate-setting stations has so far given excellent results.

After nearly 4½ years of continuous use this valve was removed from the line and dismantled for inspection. The valve was in excellent condition inside with complete absence of cavitation pitting. Since water could flow around all sides of the plug when it was in a partially open position no vacuum could be formed to contribute to cavitation plucking.

A 24-in. ball valve is being employed as an altitude valve on a new 12-mil gal prestressed concrete reservoir.

The spherical valve, (Fig. 11), which is very similar to the ball valve, can, like the ball valve, be single or double seated. If flow is in one direction, single seating on the down stream side of the plug is sufficient, but, if flow is in both directions double seating may be desirable, since pressure from the up-stream side helps to seat the valve. East Bay uses twelve spherical valves; 1—36 in. and 2—24 in. directly buried in the distribution system; 1—24 in. electrically operated by remote control, 6—24 in., 1—18 in. and 1—16 in. cast steel pump control valves, the 24 inch being electrically operated and the 18 and 16 inch being hydraulically operated by an air and oil accumulator set.

Another valve recently introduced to water works practice is an eccentric plug valve manufactured in Minnesota. From the outside this valve (Fig. 12) looks like a lubricated plug valve, but is quite different inside in that one-half of the plug is cut away and the plug is pivoted eccentrically against its seat like a ball valve or a tilting disc check valve. The eccentric plug was developed for use in the chemical industry and can be made of a number of different metals suitable for the chemical fluids which must pass through it, or, it can be made with a neoprene or rubber coated

Fig. 12—ECCENTRIC plug valve. One half of the plug is cutaway and the plug is pivoted eccentrically against the seat

plug and interior. The semi-steel valve with rubber lining can be purchased at prices comparable to those of standard gate valves. This valve is excellent for throttling and, with the addition of a few extra appurtenances, such as would be needed for gates under the same conditions, can be buried directly in the ground. It requires less room than a rising stem gate and valves with rubber coated plug and lining are bubble tight when closed. A marker on the casting indicates flow in one direction because upstream pressure helps to force the plug against the seat, but we have tested the rubber plugged valves with flow in the direction opposite to the arrow marker and they have proven to be equally tight. East Bay has 4—6 in., 3—8 in., 2—12 in., 1—14 in., and 2—16 in. in filter and pumping plant service.

Globe Valves

Globe pattern altitude valves and pressure regulators (Figs. 13 and 14) are on the market in sizes up to 36 in. in diameter. The globe valves in the East Bay system include 142 pressure regulators, 84 altitude valves, and 21 float valves, 2–16 in. in size.

The globe valve is such a commonplace item that everyone takes it for granted without realizing its widespread importance. There are very few people in the civilized western world who do not at some time during the day operate a globe valve in a water supply system. The washbasin, kitchen sink, shower, and bathtub are all supplied with water whose flow is regulated by some modification of the globe valve. The float valve in the toilet tank and the hose bib in the garden are globe valve patterns familiar to all. Early in the history of the plumbing supply industry, this valve evolved as the practical answer to the need for a device to throttle or regulate the flow of water and steam. In its simplest form, as either a globe or angle valve, a disc is forced down by a screw against a circular seat. The disc and screw constitute a single moving part in the smaller valves but in some modifications of the larger valves the disc is free to pivot on the end of the stem. As a throttling device, there has never been anything on the market to compare with the globe valve in economy, versatility, simplicity, and rugged durability.

Hand-operated globe valves are less expensive than gate valves of the same size and are very much easier to repair in the line. By removing the head, the stem and disc can be lifted out, and the body seat ring can then be unscrewed for repair or replacement. Because

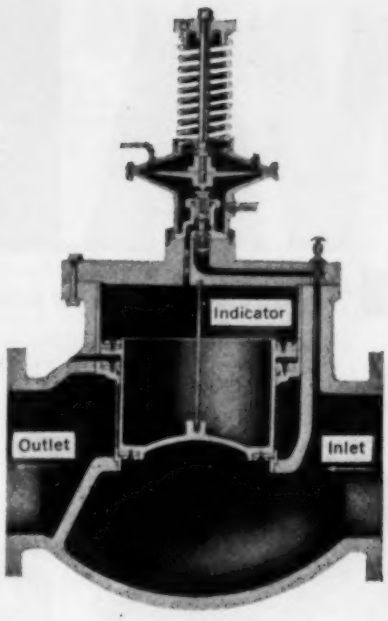

Fig. 13. GLOBE PATTERN altitude valve.

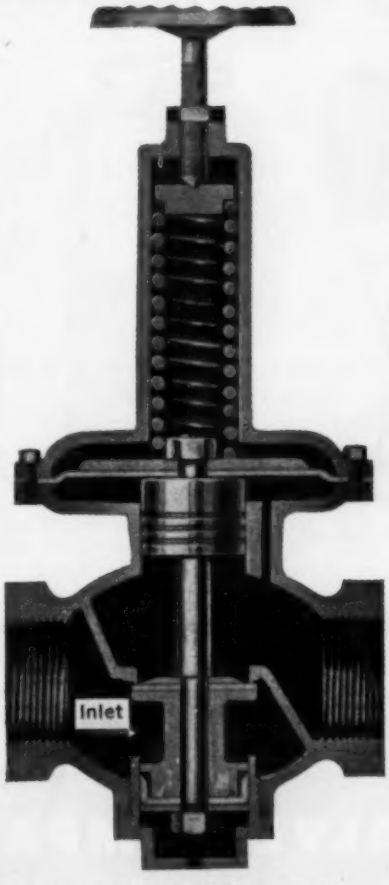

Fig. 14. PRESSURE-REDUCING globe valve.

there are no sliding parts except the screw and stem, the wear comes only from wire drawing on the disc and seat ring. Hydraulically operated globe valves of either the piston or diaphragm type are just as durable as the manually operated types. Although the driving mechanisms need occasional diaphragm, cup leather, or O-ring replacements, the interior metal parts of the valve proper are easily accessible and go for long periods without repairs. A pressure regulator that had received very hard usage over 31 years was recently removed from the line only because replacement parts were no longer available. Hydraulically operated globe valves require very little power, as the line pressure imposed on the upper side and relieved from the bottom side of the diaphragm or piston is sufficient to close or open the valve at a controlled speed. Most manufacturers adapt the same valve body castings for pressure regulators, altitude valves, relief valves, electric pump controllers, and slow-closing checks by varying the pilot control and diaphragm mechanisms.

The one disadvantage of the globe valve is the loss of head due to the devious path that the fluid must follow through it. For pressure regulators, however, this is an advantage, because energy must be dissipated anyway. If a globe valve is used as an altitude valve in installations where all of the water pumped does not reach the reservoir served by the valve (because some is intercepted by consumers), the valve size is generally determined by the required rate of withdrawal from the reservoir, which is higher than the pumping rate to the reservoir. The withdrawal rate can be augmented by introducing a swing check valve into the bypass line around the altitude valve.

Where pumps must be automatically started and stopped against a closed valve, the globe type, solenoid-controlled check valve previously described is a superior device for this purpose.

Air valves and vacuum valves, often built in combination, are very difficult to classify because there are so many kinds on the market, but most of them are either of the globe, needle, or poppet type, which can be considered variations of one another. Air and vacuum valves are used mostly for relieving entrapped air from the high points in pipelines or for admitting air to the pipeline whenever the pressure inside of the pipe becomes less than atmospheric.

Large quantities of air enter the pipeline systems when breaks occur or when lines are opened for connections

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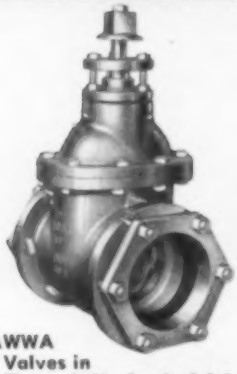

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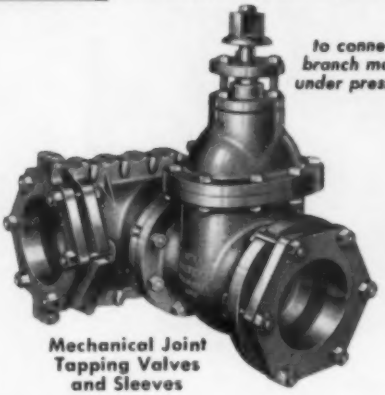
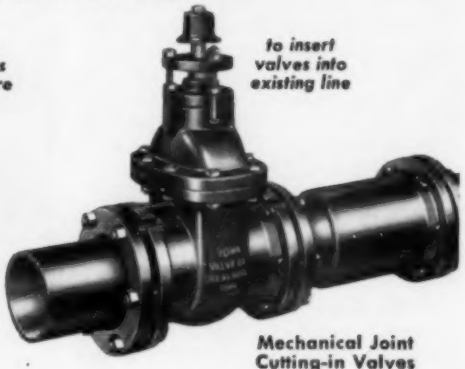


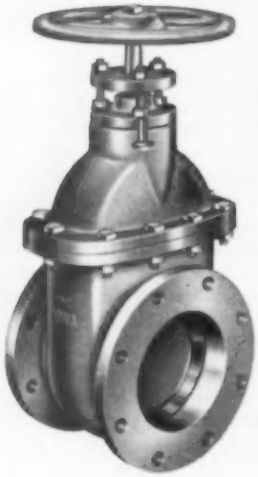
Mechanical Joint
Tapping Valves
and Sleeves

to insert valves into existing line



Mechanical Joint
Cutting-in Valves
and Sleeves

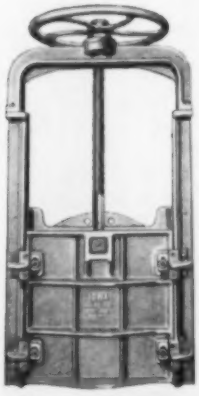
FOR FLOW CONTROL: *in sewage treatment and water filtration plants*



Flanged Gate Valves
2" through 42"

Flap Valves

Plug Drain Valves



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or repairs. When such a line is again placed in service, the air works its way to the high points, and, if it is not entrapped and released through air valves before it reaches an altitude valve or pumping station, it sometimes causes damage to equipment and inconvenience to consumers.

Vacuum valves are often unnecessary if pipes are lined and coated with Portland cement mortar or if they are buried in well compacted material. Data obtained from experiments on a 48-in. steel pipe with a wall thickness of ¼ in. and on a 36-in. steel pipe with a wall thickness of $\frac{3}{16}$ in. show how Portland cement lining and coating strengthen large-diameter pipes to a remarkable degree against collapsing *(1)*.

Early in 1951, three 54-in. dipped and wrapped tunnel outlet pipes with $\frac{3}{16}$-in. wall thicknesses, buried parallel to each other, were subjected to a vacuum of 29 in. of mercury or 14.2-psi external pressure for about 40 min without apparent damage. The same pipes, if unburied, would have collapsed under such a vacuum.

Gate Valves

Gate valves are installed by the thousands throughout the land, but they remain almost always in the wholly open position, because most of them serve as isolating valves in distribution grid systems or as protection for operating valves. A smaller number are employed as dividing valves between pressure zones, remaining closed except for inspection or an occasional emergency.

Water works gate valves are of either the solid-wedge or the double-disc, parallel-seat type. The stems can be rising or nonrising, but only the nonrising-stem valves are practical for direct burial in the ground. Even though these types have evolved through experience and tradition as the practical water works grid system valve, both have serious faults and leave much to be desired in the way of improvements in design. Because they are so common in the water works industry, they are often used as operating valves where other types would serve a great deal better.

Efforts to overcome some of the disadvantages of the gate valve have resulted in the development of the ring follower, paradox, and ring seal gates as main stops for isolating powerhouse water turbines and free-discharge operating valves in sluiceways and dams. These gates have been built to various designs and in large sizes for the US Bureau of Reclamation.

An interesting gate valve pattern, manufactured on the West Coast, is finding wide acceptance in natural gas and oil pipelines and in refinery use. It is of the ring follower type, with stainless-steel interior parts and O-ring seats, which make possible a bubble-tight valve that can be put through thousands of opening and closing operations without showing signs of wear or damage to the O-rings. This valve, which is successfully displacing other types, can be purchased in sizes up to 36 in. at prices competitive with some valves used for operating purposes in the water business (Fig. 15).

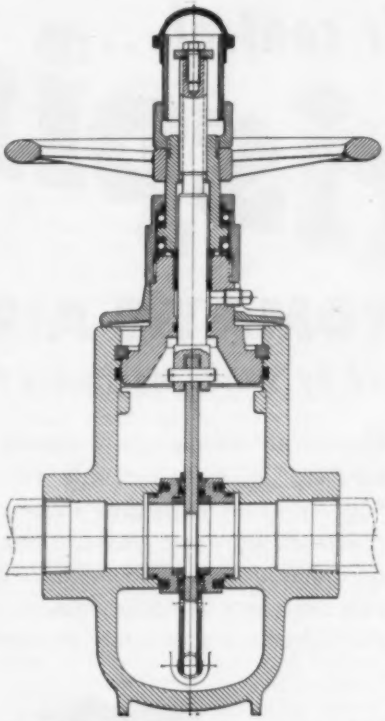


Fig. 15. RING FOLLOWER type gate valve with O-ring seats.

Throttling is the most severe service to which a valve can be subjected. Of all the valves utilized in this way, the double-disc gate is the least durable, and it should generally be limited to service as an isolating valve, an application in which, owing to its relatively low initial cost, practical experience has found it to excel. If a gate valve is intended for throttling service, the solid-wedge variety, with close-fitting guides, should be selected. Square-bottom and beamed-waterway double-disc types are widely used as wash water valves in filter plants, under conditions of low head and velocity.

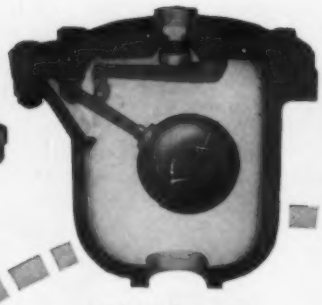
The beamed-waterway double-disc valve is equipped with bronze-faced beams located in the downstream part of the valve body. Bronze strips on the downstream disc match and are opposite the beams, and the disc and beam facings are flush in the same plane with their respective disc and seat rings. This arrangement prevents the disc from tipping obliquely into the seat ring and very effectively prolongs the life of the valve. The square-bottom valve has shoes that are attached to the downstream disc at three points and slide on tracks, two in the valve body and one in the bonnet. In this manner, the disc is held away from the seat until the shoes slide off the tracks at the end of closing travel and allow the disc ring to engage the seat ring without scraping. These valves can be of either the "single" or the "double" square-bottom type, according to whether the flow through the valve is to be in one direction or two. Although the beamed-waterway and square-bottom arrangements save wear on the seats, a disproportionate amount of power is still needed for operation, and bypass valves and gear trains or hydraulic cylinders are necessary accessories to most gate valves larger than 16 in. in size.

Gate valves can be power operated by any of the methods used for any other type, but the power requirements of the former are much greater because of the sliding parts. The most common means of operation are hydraulic cylinders and electric motors, but pneumatic operation is coming into wider use.

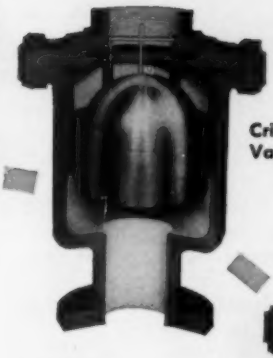
In general, East Bay uses nonrising-stem double-disc valves for direct burial only. For isolating valves in pumping plants or other installations where the valve is in the open or in a pit and there is sufficient room to accommodate the extra length, the rising-stem valve is utilized. Some 90 per cent open, lubricated plug valves are also employed for the latter purpose.

The solid-wedge type has two moving parts in the valve proper, both of which are subject to unlubricated sliding friction, where the square- or acme-threaded stem screws into the wedge and where the wedge guides slide on close-fitting guides in the valve body. The wedge is usually of solid brass or bronze or, like the body seat rings, brass or bronze mounted. The wedge faces do not come in contact with the seats until the valve is closed. If the valve remains in the open position for a long period in a grid system carrying water that causes lime or other solid matter to deposit or tubercles to develop in the recess between the seats, the valve will not close completely and too

Crispin Midget Valves



Crispin Pressure Valves



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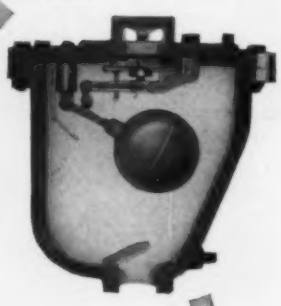

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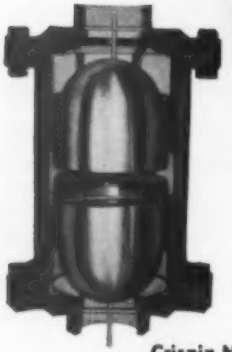

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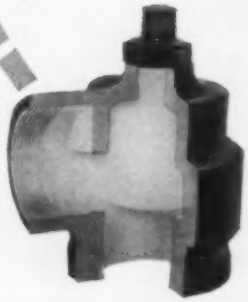
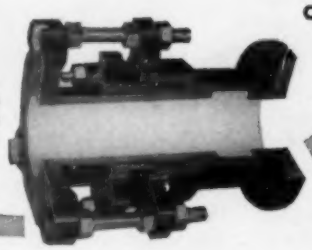


Crispin Slip Joint



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much effort to force it will break the stem. Also, if this valve is installed in the tightly closed position when the temperature is high and is left closed after cold water has been introduced into the system, it may be very difficult to break the valve loose to open it. The valve has a tendency to stick in the closed position even when there is no temperature change. A number of manufacturers produce these valves only in the smaller sizes, which are used by some large water works systems in great quantity. The solid-wedge valve is favored in some industrial, refinery, and steam plant applications. An advantage of the solid-wedge gate lies in the fact that it can be installed and operated in any position—horizontally, vertically, upside down, or with the leaf in a horizontal plane. (East Bay discontinued the use of single-wedge gates about 15 years ago because they are difficult to repair, especially in setting them up in machines for accurate refacing so that the wedge faces on the disc and body could be fitted true and tight.)

The double-disc, parallel-seat gate is an awkward mechanical device, with four to ten moving parts in the valve body proper, each of which slides or scrapes without lubrication against some other part. Double-disc gate valves are designed primarily for use in the vertical position with the stem upright, but they can be operated in the horizontal position. The loose parts of the wedging mechanism work best when hanging in the vertical. Valves 16 in. and larger, installed horizontally in horizontal pipelines, should be equipped with tracks, rollers, and scrapers. The installation of double-disc gates in vertical pipelines should be discouraged, even if tracks are placed in the bonnet to support the edge of the lower disc. Double-disc valves will not operate upside down or at any angle with the stem below the horizontal, because the wedging mechanism engages and jams the discs against the seats. Moreover, accumulations of solid matter trapped in the bonnet will interfere with the operation of the valve.

Nearly every manufacturer has his own method of spreading and wedging the discs against the seat rings in the closed position. The advantages of some of these methods are subject to argument. A single good standard design for a wedging device in gate valves is badly needed. For valves 12 in. or smaller, this design should permit the stem to be changed with the discs wedged closed and the line under pressure.

As the two discs hang loosely inside the valve bonnet, the downstream disc edge tips into the waterway and gouges into the seat ring at a slightly oblique angle when the valve disc passes between the open and closed position, causing uneven wear on these parts. If a double-disc valve is allowed to remain in a partly open or throttled position for any length of time, the constant vibration or chattering of the discs in the stream soon causes wear in the small links required in some designs to hold the leaves parallel; when the links finally wear through and come off, enough displacement of the discs often occurs so that the hooks and wedges drop out and are carried away in the stream. Gate valve parts have occasionally been found at considerable distances from the places where the valves were located.

In the double-disc gate, the outside of the two discs and the protruding end of the stem are the only portions of the moving parts that can be seen without disassembling the valve. The other parts are hidden from view between the leaves or in the bonnet of the valve.

East Bay recently sent a questionnaire to some gate valve manufacturers and large users in order to establish a cross section of opinion on what constitutes good practice for gate valves equipped with grease cases and intended for direct burial. Not only were the answers conflicting, but some manufacturers even contradicted themselves when the same question was asked in a different way. There appeared to be no standard practice based on factual observation of or experience with grease cases among either users or manufacturers. Some of the latter seemed to have an unsympathetic and unrealistic attitude toward the users' problems and gave the impression that, as long as gate valves are made and sold in the traditional manner, the user should be satisfied with what the market has to offer. One or two suggested that, even though the grease was driven from the case by water under pressure, the valve could still be operated.

It must be concluded from the questionnaire returns that manufacturers and users of gate valves do not know whether or how long an integral type of gear case remains free of water after the valve has been installed. The attitude seems to be that what cannot be seen cannot be known and what is not known is not important. Yet what assurance is there that, in an emergency, a large distribution line gate valve can be closed if it has remained untouched for a long period, with discs forced out against the top of the body seat rings by tuberculation and corrosion products?

Based on experience during the past few years, very rigid specifications on gate valves have been drawn up by the East Bay District. These specifications require delivery of the larger gate valves to East Bay shops for dismantling and inspection. Any valve that is not in compliance with the specifications must be corrected.

Conclusion

A variety of good check valve types is available on the market, some one of which, in any given situation, are better than the others.

The traditional gate valve, up to 16 in. in size, has earned top consideration in the water works industry as an isolating valve.

The traditional gate valve is the least durable and the most difficult to operate of all valve types practical for water works service. Users of valves in sizes 24 in. and larger would do well to consider the application of various types other than gate valves, regardless of whether they are intended for isolating or operating purposes.

Acknowledgment

The cooperation of valve manufacturers in furnishing illustrations used in this paper is gratefully acknowledged. Names of manufacturers have been omitted throughout, in order to avoid the implication, erroneous in some instances, that the same type of equipment is not available from other firms.

Reference

1. Paul, Leslie & Eide, O. F., Crushing Strength of Steel Pipe Lined and Coated With Cement Mortar. *Jour. AWWA*, **44**:525 (Jun. 1952).

Ten Packing "Don'ts" Worth Heeding

It is well known that "don'ts" are often more effective than "do's," so here are some suggestions and warnings arranged as "don'ts" that are based on many years of practical experience. They will be found useful in connection with the selection and installation of packings. To follow them may mean freedom from trouble that would occur when even the best obtainable packing is improperly installed.

1—DON'T fail to make clear what the packing is to pack. In other words, with what will the packing make contact?

2—DON'T guess at a size, diameter, width or height when ordering packings. Many failures have resulted from small errors in dimensions.

3—DON'T allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall; 1/16 to 3/32 inch on each side, depending on size of packing, is usually recommended.

4—DON'T doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.

5—DON'T apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean so sediment will not collect in cylinders and wear the packing.

6—DON'T apply cup packings to end of plunger which is badly worn; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.

7—DON'T apply "U" packings where plungers are worn without reinforcing under heel with leather cushion rings.

8—DON'T look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.

9—DON'T allow water to corrode cylinder walls, plungers or rods. Use an anti-rust agent that will prevent this and that will act as an effective lubricant.

10—DON'T squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set glands up to point where "U" packings are free to function properly.

Contributed by *W. F. Schaphorst*, M. E., Newark, N. J.

How To Pack A Stuffing Box

1. Remove all old packing from the stuffing box.
2. Clean box thoroughly, removing accumulations from walls.
3. Keep packing clean during application. The scoring of rods, shafts or sleeves often results from grit or foreign matter picked up by packing.
4. Determine size of packing required by checking diameter of rod or shaft and the inside diameter of the stuffing box. Rods wear and the packing has to compensate for this wear.
5. Never wind a length of packing into a stuffing box. Use ring form only.
6. Cut spiral or coil from packing over a shaft or mandrel of exactly the same size as the one on which the packing is to be used in order to get close fitting rings.
7. Obtain sharp clean cuts on soft packings that tend to squash or become ragged by simply applying a small piece of friction tape at the place where the packing is to be cut. It is advisable to remove the tape when installing the rings. String also serves well for tying the packing on each side of where the cut is to be made and may be left on the packing when installed.
8. Cut all packing ring joints to a snug fit making the rings meet with a tight butt or bevel joint.
9. Seat each packing ring carefully before placing the next one in the box. Loading a stuffing box with packing and then pulling up on the gland follower may cause excessive deformation of the first two rings, building up localized gland pressure and failure to seat the bottom rings so they can work effectively.
10. Install all packing rings so that joints are staggered and kept approximately 90 deg. apart. Spot joints in clockwise direction to facilitate locating them when removing packing.
11. Pull up the gland follower sufficiently tight, after the packing has been installed, to insure final seating of the packing. The nuts should be backed off two or three turns to relieve excessive pressure. Adjust packing to operating conditions.
12. Keep the following in mind for stuffing boxes provided with water, oil or grease lanterns: (a) Make sure that the lantern is so located in the box that as the packing is taken up, the lantern will be advanced to its proper location with respect to the opening in the box. (b) Check to see that the opening into the stuffing box is free from obstructions so that the sealing water or lubrication can flow into the lantern.
13. Allow packing to leak a small amount, if possible, when starting a newly packed pump. Take up the gland slowly as the packing seats.
14. Provide means for lubricating the rod and packing wherever possible.
15. Finally, carefully wrap all extra packings, place them back in their container as a precaution against waste and the possibility of their picking up dirt and other injurious foreign substances.

Courtesy of *Power*

Helpful Hints For Handling Packings

1. Use packings of correct size. Oversize packings are difficult to install and may cause excessive friction. Undersize packings may be ruined by too much takeup.
2. Where leakage cannot be permitted, provide a means of introducing a sealing or lubricating fluid such as water, oil or grease into the stuffing box.
3. When renewing packings, use all new, clean packing. Worn packings are dry, highly compressed, have high friction, may develop scoring.
4. Remember packing is relatively cheap. Labor and materials necessary to replace worn shafts, sleeves or rods are expensive and critical commodities.
5. Take up bolts evenly, moving to the bolt diametrically opposite, never to the bolt adjacent.
6. Follow up bolts the next day after installing new gaskets. For lines carrying high pressures, the gradual building up of the pressure and continuous follow-up of bolts is recommended.
7. Exercise great care when using gasketing dopes. Never use oil or grease on a rubber or rubber-compounded gasket. Graphite and glycerine or molasses compounds are not injurious to rubber. Never use dope on both sides of gasket—it may cause slippage or blowout.
8. Do not use a heavier sheet packing than is necessary. The thinner the gasketing material, the better.
9. Ring gaskets are preferable to full face gaskets where the flanges are heavy enough to prevent distortion.

Courtesy *Johns-Manville Corp.*

Gate Valve Design and Application*

By G. J. MANAHAN

General Sales Manager, The A. P. Smith Manufacturing Co., East Orange, N. J.

THE GATE VALVE is one of the oldest practical devices known and the one most frequently employed to control the flow of fluids and gases in pressure conduits. The term "valve" is now applied to any device that opens and closes and provides a passage-way for fluids and gases.

Historical Background

The earliest form of mechanical valve was the bellows which was used by the Egyptians 3,500 years ago. Paintings on the walls of a tomb of that period picture a bellows with bamboo piping used to smelt ore. The next development was the flap type valve which allowed fluids to travel in one direction in open and low-head conduits. Grecian illustrations dating about 600 B.C. depict showers used for bathing which involved the discharge of water controlled by flap type valves. About 250 B.C., a Greek developed a two-cylinder pump which employed a valve in connection with the functioning of each cylinder.

A century or more before the Christian era, Hero of Alexandria is credited with the development of the first workable hinged valve involving a flat gate which was opened and closed to admit water and control the discharge of pumps. In his writings, Hero wisely stipulated that the seat facings should be smooth and polished to insure a reasonably tight closure.

The fourteenth century thinker, artist and egineer, Leonardo daVinci, left many drawings of valve constructions, the most advanced of which was the multiport check valve which involved four pairs of hinged gates. Today multiport valves find a ready use in water and sewage facilities.

Prior to the eighteenth century, pressure conduits were not generally employed because a satisfactory piping material was not available. Early in the eighteenth century, the first cast iron pipe was installed and in 1795, Joseph Bramah designed a valve stem featuring a screw thread which was used to open and close sluice type valves.

In 1839 James Nasmyth designed the first practical metal gate valve which was immediately employed by the East London (Eng.) Water Works. The Nasmyth design consisted of a cast iron body and bonnet, a threaded valve stem and a solid tapered plug.

Solid wedge, taper seat valves were introduced in the United States a few years later. About 1845 existing water utilities started to employ gate valves in pressure piping. Operating pressures were moderate, pipe sizes were reasonably small, and most of the valve development work related to small diameter and low pressure valves. The major changes and refinements of the original Nasmyth solid wedge, taper seat valve took place between 1845 and 1895. During this period, double disc, parallel and taper seat gate valves were developed and met with wide and continuing use. The first double disc, parallel seat gate valve was of the bottom wedging type and was followed by center and side wedging types.

Gate Valve Types

The solid wedge, taper seat gate valve design has not been changed basically during the past 110 years. In this design, it is essential that the taper of the plug must coincide exactly with the taper of the body seats to achieve a pressure seal or shut-off. To prevent the plug from being moved in the direction of the downstream seat by the flow during the operating cycle, and to eliminate valve stem strain and undue seat face wear, plug guides should be integral with the valve body. The guides should have non-ferrous metal facings. As valve sizes increased, it was found that the problem of maintaining a perfect mating of the plug taper and the body seat taper was difficult and expensive to achieve. It was also noted that the body seat taper was distorted as operating pressures and dead weight piping loads transmitted to the valves increased, with the result that leakage took place.

The Coffin double disc taper seat gate valve was developed in 1867 to obviate and minimize the distortion of the body seat and the resulting leakage.

Double Disc, Parallel Seat, Bottom Wedging

S. J. Peet, in 1875, patented the double disc, parallel seat, bottom wedging type gate valve (Figures 1 and 2). In this design, the discs move downward until the lower wedge travel is terminated by contact with a stop in the bottom of the valve body. The discs and upper wedge continue to travel until the wedges contact one another, thus forcing the discs against the body seats. In opening, the first turn or initial movement of the valve stem releases the wedges freely to the open position. Suspended solids which are sometimes present in the bottom of piping can be entrapped by the bottom wedge, changing the contact elevation, thus occasioning preliminary or early wedging with the discs in a partially open position.

*Reprinted from *Sew. & Ind. Wastes*, Vol. 25, No. 2, p. 225 (1956)

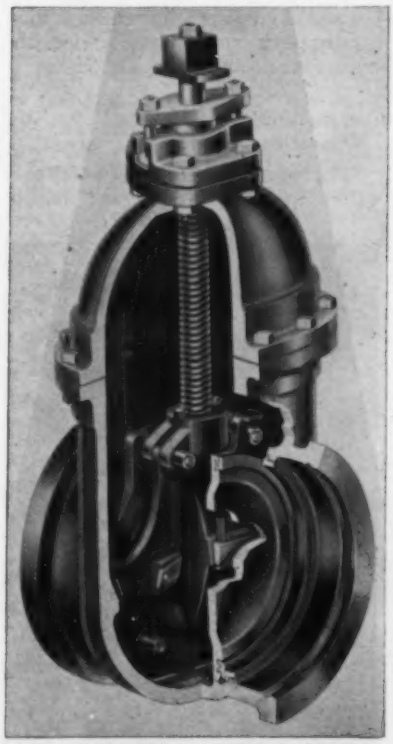


FIG. 1.—EXPOSED view of a double disc, side wedge, parallel seat, non-rising stem gate valve.

Double Disc, Parallel Seat, Center and Side Wedging

Center and side wedging, double disc, parallel seat type gate valves were developed and introduced late in the nineteenth century. In the side wedging design, the discs move downward until the travel is terminated by contact with stops in the bottom of the valve body, at which point the disc faces fully cover but are not in firm contact with the body seat ring faces. The final rotation or movement of the valve stem actuates the wedging mechanism expanding and forcing the disc faces against, and in contact with, the body seat faces, producing a drop-tight shut-off. The wedging mechanism is actuated by inclines integral with the valve body located near the horizontal centerline of the valve; thus, suspended solids and foreign matter in the bottom of the piping cannot occasion preliminary or early wedging. In opening the first turn or the initial movement of the valve stem releases the wedges before the discs move, thus the discs are free to travel to the open position without undue surface friction.

Square Bottom Case and Disc

Manual, cylinder and electric motor operated gate valves which will be subject to frequent operation and in service will be either in a fully open or a fully closed position should be of the square bottom case and disc type. This construction prevents the downstream disc from tilting into the downstream port opening. The disc and disc rings, at the bottom, are essentially square with the result that a substantial area of each disc ring is in contact with each body seat ring during the operating cycle. Disc ring and seat ring wear is thereby reduced to the practical minimum.

Valves installed in a flat position in vertical piping should be of the square bottom case and the disc construction with bronze tracks secured in the top of the valve body and in the bonnet, providing parallel surfaces supporting the discs during the operating cycle.

Beamed Waterway

Valves which will be subject to frequent operation, substantial unbalanced pressure, high velocity and will be used to control flow should be either beamed waterway (Figure 3) or single throttle construction if the flow is not subject to reversal. If the flow is subject to reversal, the valves should be double throttle construction.

The beamed waterway valve design prevents the downstream disc from tilting into the downstream port opening. Bronze faced beams located on the downstream side of the valve body register with bronze facings securely attached to the donwstream disc. The beam faces and the disc facings are in the same plane as the disc and seat ring faces. The beams prevent disc tilting and in combination with increased contact bearing area, uneven disc and seat ring wear is eliminated.

Throttle Construction

Throttle construction mechanically lifts each disc ring face out of contact with each seat ring face during the entire travel of the discs. This construction (Figure 4) stops disc tilting, uneven disc and seat ring wear and chatter. Throttle construction valves are suitable for installation in vertical, horizontal (on edge) or in flat positions in vertical pipelines. The disc and seat ring faces are not in contact while the valve is in a partially open position or while the discs are moving.

Throttle construction discs are provided with three non-ferrous metal shoes. One shoe is attached to the disc at the top centerline, the other shoes are attached to lugs which are integral with the disc, one on each side near the bottom of the disc.

The throttle construction valve bodies have three non-ferrous metal tracks. Two tracks are located and securely attached to the body, one on each side of the body seat ring. The third track is located and securely attached at the top centerline above the seat ring. This track extends into the valve bonnet.

As throttle construction valves begin to open, the disc shoes slide up inclines at the bottom of each body rail lifting and holding the disc ring face out of contact with the body seat ring face. In closing, the disc shoes slide down the tracks and the inclines at the bottom of each track until the disc ring face is in contact with the body seat ring face thus permitting the wedging of the discs in the closed position.

The three disc shoes register with the three body rails and are in contact with one another while the valve is unseated and in a partially open position. The non-ferrous metal disc shoes and body rails are designed with ample bearing capacity. Throttle and/or beamed waterway construction thus assures long gate valve service life under severe operating conditions.

FIG 2.—FLANGED (O.S.G.Y.) rising stem, double disc, side wedge, parallel seat gate valve.

Construction and Operation Features

The several basic types of gate valves briefly described are usually

FIG. 3.—EXPOSED view of beamed waterway valve construction.

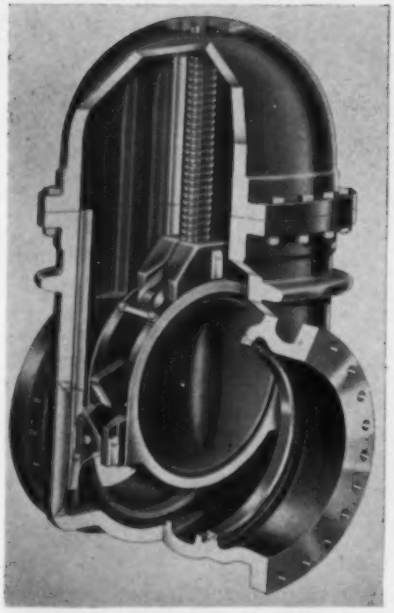


FIG. 4.—EXPOSED view of throttle construction gate valve with disc shoes and body tracks.

manually operated, employing key wrenches, handwheels, chain wheels or floorstands. They can, however, be cylinder or electric motor operated. Manually operated gate valves are either of the non-rising stem (Figure 1) or of the rising stem type (Figure 2). The operating threads of non-rising stem valves are always in contact with the fluid or gas in the valve body, whereas the operating threads of rising stem valves are outside of the valve body and, therefore, are not in contact with the fluid.

Gate valve constructions and refinements introduced during the twentieth century include "O" Ring pressure seals, position indicators for non-rising stem valves, valve body clean-outs, gearing, by-pass valve assemblies, tracks, rollers and scrapers, square bottom case and disc throttle and beamed waterway construction.

"O" ring pressure seals replace conventional valve stem packaging (Figure 5) and reduce maintenance to a minimum. Position indicators for non-rising stem valves establish visibly at all times the position of the valve discs or wedges. Rising stem valves do not require position indicators as the valve stem serves as an indicator

Valve body clean-outs should be provided on all gate valves which will be in service in piping conveying suspended solids in solution. The cleanouts should be inspected periodically to flush the suspended solids from the valve body and from contact with the internal operating parts of the valve.

Gearing and by-pass valves are used to reduce the torque required to operate large valves. By-pass valves are also used to fill the line on both sides of the valve thus balancing the pressure before the main valve is opened. Enclosed gearing is normally applied to valves 14 in. and larger in diameter, which in service will be used at or near the working pressure rating.

Vertical valves are normally equipped with spur gearing; horizontal valves with bevel gearing. Horizontal valves installed on edge in horizontal piping should be equipped with bronze tracks, rollers and scrapers. The bronze tracks and rollers carry the weight of the discs during the operating cycle.

Many types of valves are available and employed in connection with the numerous and varied sewage and industrial waste services which require valves including gate valves, butterfly valves, diaphragm valves, lubricated and non-lubricated type plug valves, eccentric rubber-faced plug valves, rotary cone valves, mud valves, shear valves, flap valves, foot valves and sluice gates. Each type of valve has limitations from an employment, operating and economic standpoint. The full operating conditions to which each valve will be subjected should be examined carefully and should be reflected in the determination of the type of valve to use for each control and shut-off service. Unfortunately, many types of valves are subjected on occasion to operating conditions beyond their design and recommended limits.

Operating pressure frequently is a deceiving criterion when it is used to determine the test pressure rating of the valve to be employed. More important criteria include frequency of operation, speed of operation, velocity and the nature of the fluid from the standpoint of the pH and the suspended solids content.

The minimum desired service life of valves is generally considered to be 50 years. To insure long service life with minimum maintenance, maximum valve construction should be considered with respect to pressure rating, shell thickness, trim composition and trim dimension.

Sewage and Industrial Waste Service Applications

1. Non-rising stem gate valves should not be used in piping conveying sludge or heavy concentrations of suspended solids because the operating threads would be in contact with the fluid and solids in the valve body. Rising stem gate valves should be used in exposed accessible piping. The operating threads are outside of the valve and not in contact with the fluid. The valve stem serves as a position indicator.

2. Gate valves used in lines conveying moderate concentrations of suspended solids should be of the center wedging or side wedging, double disc type. The discs in this type valve are free from pockets in which solids would collect. The valve body should have clean-outs which permit the periodic flushing of solids from the body and the operating mechanism.

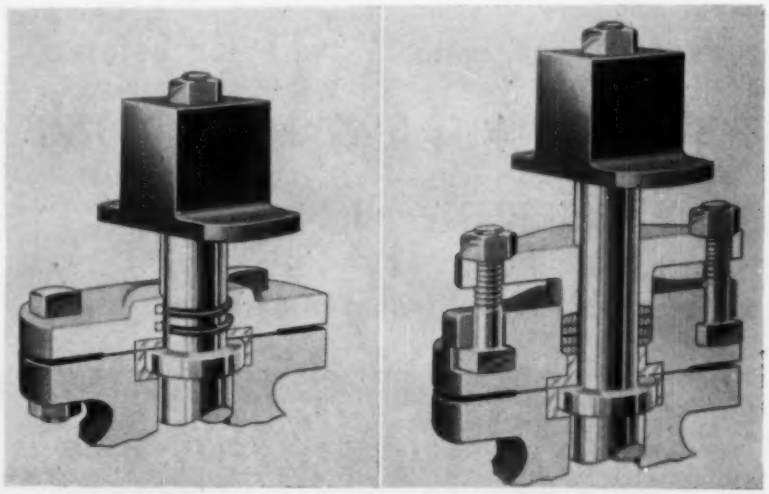


Fig. 5.—EXPOSED view of "O" ring seal plate (left) and conventional stuffing box and packing (right) used on non-rising stem valves.

3. Double disc gate valves should not be installed in an upside-down position in horizontal piping unless the manufacturer has been advised of the installation position and provision made in the valve construction to compensate for this unusual service requirement.

4. Gate valves which will be operated frequently and when in service will be either in a fully open or closed position should be of the square bottom case and disc type.

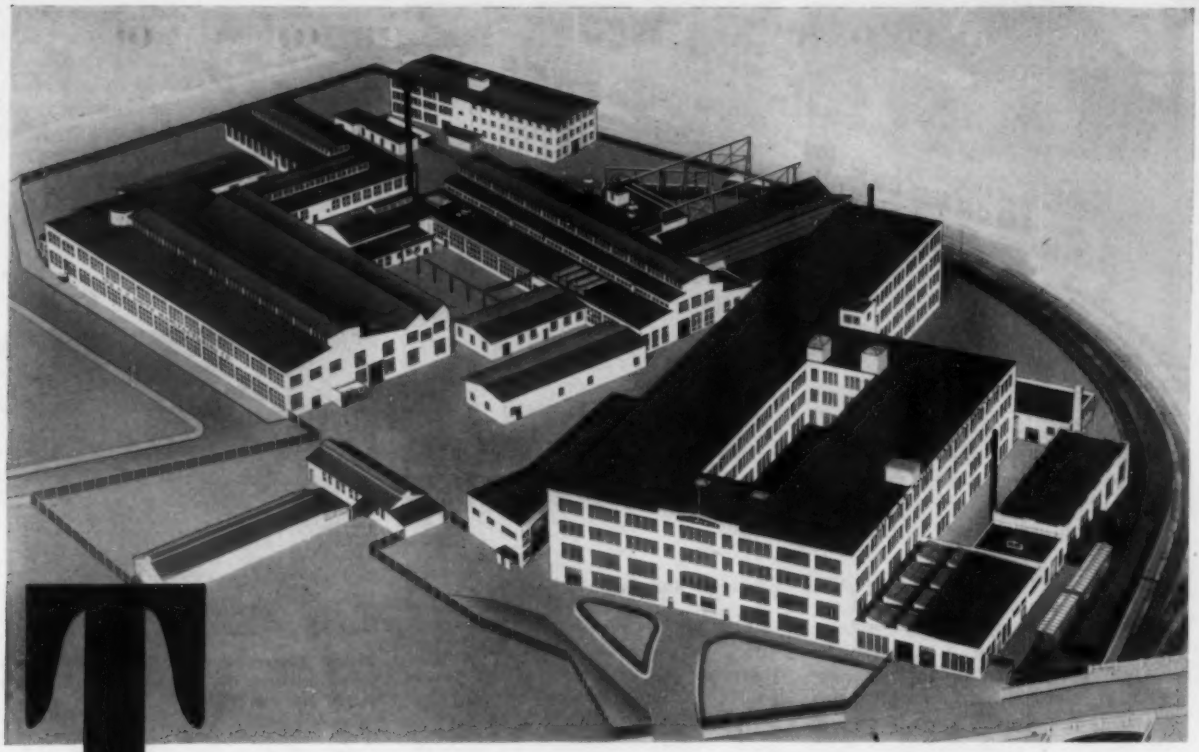
5. Gate valves subjected to frequent operation, substantial unbalanced pressure, high velocity and used to control flow should be of the beamed waterway or throttle track type.

6. Gate valves, sizes 14-in. and larger, should be equipped with gearing if the valves will be subject to an operating pressure at or near the recommended working pressure. These large gate valves should be equipped with by-pass valves permitting pressure equalization before the main valve is opened.

7. Valves placed in inaccessible locations should be operated by a floorstand, chain wheel, cylinder or electric motor. Cylinder operation is economical because the source of power is usually provided from existing installations. Cast iron, bronze-lined, hydraulic cylinders should be used as they are extremely rigid and assure long service life under severe operating conditions.

8. The valve manufacturers should be advised concerning the type of service and the characteristics of the fluid in the piping so that the valve will be of appropriate construction and equipped with the proper metal trim.

9. Gate valves should be operated at least twice each year. Valve stuffing boxes should be checked and adjusted at least four times a year. Proper and timely maintenance will insure long, efficient gate valve service life.



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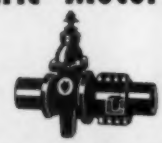
produces, FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types. GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service.  INSERTING VALVES sizes 4" thru 48" for inserting under pressure. TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.

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Repair and Reconditioning of Lubricated Plug Valves

Often returns them to their peak efficiency

by PAUL A. MANOR

Chief Engineer, Barberton Division, Rockwell Manufacturing Co.

AS IN MANY chemical or processing plants, valves in water treatment and sewage disposal installations can frequently determine the success or failure of an operation. They deserve the same type of careful service as more spectacular types of equipment such as chlorinators, filters, and aerators.

From an economic standpoint, spending money to repair and recondition ancient valves would seem reasonable. Whether a certain valve justifies repair is an individual matter, however, and should be decided by comparing the estimated cost of repair with the cost of buying a new valve.

Even after years of service, lubricated plug valves can often be returned to peak efficiency simply through cleaning, inspection, and reassembly with new packing and gaskets. The purpose of this article is to present a basic guide for reconditioning or repairing these valves.

Cleaning and Examination

The valves should be cleaned as much as possible before taking them apart. After completely disassembling the valve, use any solvent or alkaline solution to clean the parts. Apply wire brushing or abrasive blasting to clean corroded areas. Tapered seats of both body and plug should be carefully examined for corrosion, pitting, scoring, galling, or erosion. For plugs having integral shanks, check the diameter of the machined shank. Also, examine the shoulder adjacent to the plug shank for corrosion or erosion.

WIRE BRUSHING to remove deposits from corroded areas; abrasive blasting might also be used

LUBRICATING 12-inch valves at pressure-reducing station, Santa Barbara, Calif.

Repairing the valve depends on how seriously the seating surfaces of both plug and body are scarred. The following are some typical cases:

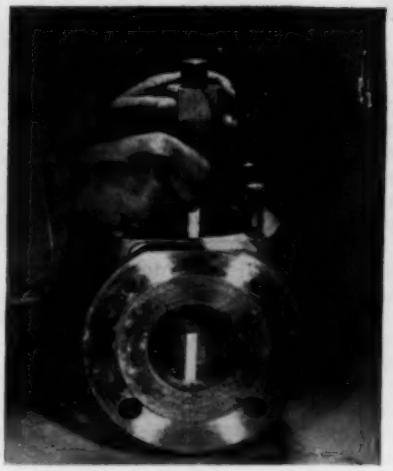
Case 1. Corrosion or scoring is very shallow. Here, the valve can be salvaged by relapping the plug in the body. Machining the seating surfaces of either the body or plug is unnecessary. For integral-shank plugs, however, the shank diameter and adjacent shoulder must be resurfaced by grinding before relapping.

Case 2. Corrosion, galling, or scoring is moderately deep. Remachining the tapered seating surface in the body is necessary. This usually requires an oversize plug to match the oversizing of the taper bore.

Case 3. Severe corrosion, erosion, galling, or deep scoring. Before machining the valve body bore, the worn areas in the body must be rebuilt to restore the tapered seating surface. Rebuilding may be done by any standard welding or brazing process.

Valve plugs are individually fitted and lapped to valve bodies by the manufacturer. Consequently, replacement plugs are furnished in oversize dimensions with a semi-finished taper. Excess metal is allowed, therefore, for fitting the plug to rebored valve bodies. Most valve bodies have extra metal at the tapered section; this permits one or more reboring operations without reducing the body's wall thickness below allowable limits.

CHECKING DEPTH of lubricant groove is one step in valve examination



CHECKING TAPER with feeler stock. Valve bodies can be machined

Remachining Valve Bodies

Use either an engine lathe or a vertical boring mill to remachine valve bodies. Obtain a taper attachment or ram for the lathe or mill, capable of producing a taper angle of 4½° from the centerline of the valve body.

To be on the safe side, make a trial cut on scrap to check both the accuracy of the taper angle and the overall setup. Then make the initial cuts on the valve body to remove all blemishes. Take the final, finish cut very lightly and with a fine feed in order to obtain a clean, smooth, true taper bore.

Accurate work cannot be obtained unless the spindle, tool carriage, and machine ways are in good condition and are properly adjusted to avoid "lash." These precautions are particularly important when finish-boring plug valve bodies because of the interrupted cut when the tool passes over port openings.

After machining the bore, check the lubricant grooves or ducts on the valve body. If any are shallow or missing, they should be deepened or reproduced by either chipping, machining, or grinding. Similarly, valve bodies which require rebuilding of worn areas prior to machining must have the lubricant grooves or ducts remachined.

Machining Plugs to Fit Valves

For valves consisting of:

1. Iron alloys and bronze—

Oversize plugs are shipped centered and finish-machined (except for the taper section).

Place the plug between centers in a lathe. Adjust the taper attachment on the lathe 4½° from the centerline of the plug.

First, take caliper-and-scale dimensions from the valve body to machine the taper on the plug. Don't machine too far. Leave enough metal for final matching of taper and diameter.

After machining the plug so that it sinks partially into the body seat, check the taper angle by placing strips of "feeler stock" between the plug and body near both ends of the taper. If necessary, make light trial cuts. Adjust the lathe taper attachment after each cut until an exact fit is obtained.

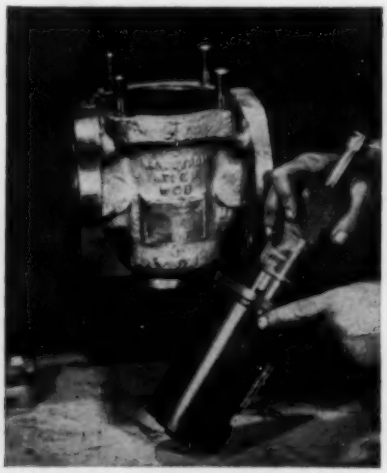
After the taper is exactly matched, make additional light cuts until the plug enters the body with the plug shoulder **below** the body gasket seat a distance about equal to the minimum dimension allowed by the manufacturer. Thus, for the final lapping operation, the plug can shrink slightly further while still remaining within its allowable dimensions.

2. Steel—

Plugs for steel valves require a hardening treatment between ma-

APPLYING lapping compound to bearing surface of plug

LAPPING valve by hand, final step in making close fit



CHECKING accuracy of fit with valve which has been blued

chining and lapping operations to prevent galling and sizing in the valve body. Steel replacement plugs are furnished soft so that a taper can be easily obtained to fit rebored bodies. Don't try to rebuild steel valve bodies unless heat-treating and grinding equipment is available for hardening and shaping the plugs.

Turn the plug to fit the body bore, as previously described for semi-steel valves. About 0.020 to 0.040 in. of additional metal must be left on the plug taper to permit grinding after heat treatment. Heat, quench, and draw the plug to obtain a medium hardness on the taper surface. Plugs with integral shanks should be quenched on end to minimize warping.

After hardening, grind the plugs between centers to finish them. The procedure for fitting the taper in final position in the valve body is the same as for iron alloys.

Lapping

The final step in obtaining a close fit between valve body and plug is to lapp the respective bearing surfaces with an abrasive. Lapping cannot be used to correct mistakes in previous machine work. Excessive lapping may cause the plug to fit too deeply in the valve body. Only enough lapping to take out tool and grinding marks and to produce a smooth finish on the taper surface should be necessary.

Before starting to lapp, use either a file or emory cloth to smooth all sharp edges on both body and plug.

Valves may be lapped either by hand or with a drill press. If a drill press is used, secure the valve body to the base and rotate the plug through a floating attachment connected to the spindle.

For a lapping compound, use 200-grit aluminum oxide for steel valves and 200-grit silicon carbide for iron valves. A non-lubricating oil emulsion should be used to keep the compound in suspension.

When lapping, lift the plug about ¼ to ½ in. out of the valve body after each four or five revolutions. Sufficient space should be provided between plug and body to permit the lapping compound to spread evenly.

Continue lapping until all machining marks disappear and the surface shows a uniform "matt" finish. Rotation of the plug in the body should now show an even metal-to-metal contact, without excessive bright or dark areas. The accuracy of the fit can be checked by blueing the plug into the body and rotating it one or two turns under light pressure. Any mismatching, off-taper, or out-of-roundness will show clearly when the plug is removed and examined.

The same requirements as indicated for lapping with a drill press hold true for hand lapping. In the latter case, however, the plug is usually oscillated four or five times between each lifting of the plug out of the body.

After the lapping is completed, the depth of the plug in the body should be checked against the manufacturer's specifications.

Head Loss in Butterfly Valves

by H. W. HAMM
Design Engineer, S. Morgan Smith Co., York, Pa.

BUTTERFLY valves are frequently used in water supply and in wastes disposal systems because they have the following characteristics:

1. The flange to flange dimensions are small, resulting in space saving.

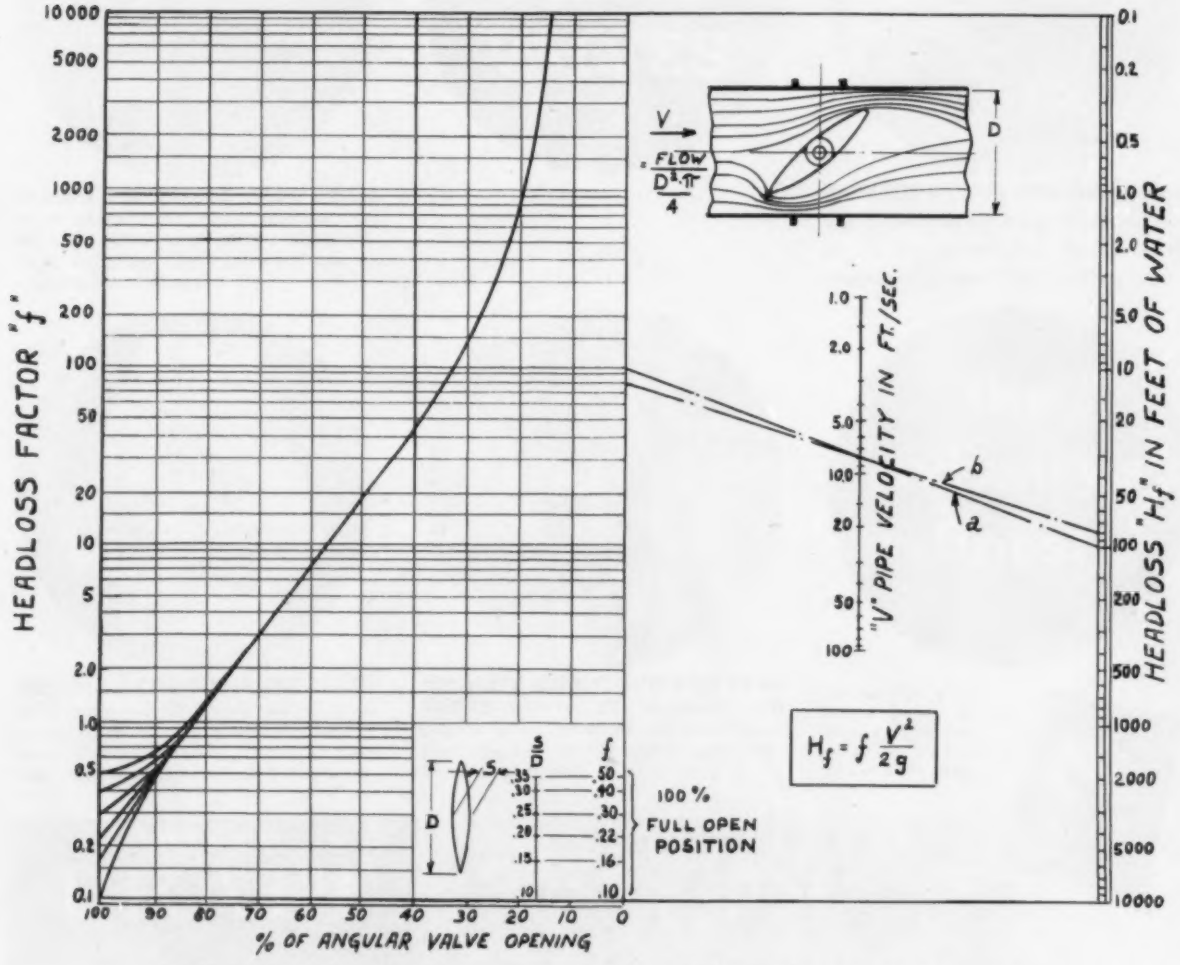
2. The operating mechanism is simple and rugged, is located outside the valve body, and therefore is easily accessible and not subject to corrosion.

3. The cost is low.

These advantages are to some extent offset by the head loss, which in the full open position is slightly larger than that of other valves, also, by the small amount of leakage which in valves without special seats is inevitable.

Knowledge of the head loss for the full open position is useful. Also, when the valve is used for regulating the head losses at the several intermediate positions is valuable. The accompanying chart gives the head loss factor on the left side and the head loss on the right side. When a valve is equipped with a disc position indicator, the chart can be used to set the valve for any desired flow.

Lines "a" and "b" illustrate use of the chart. Line "a" is for a 24-inch valve in a setting where the static head



BUTTERFLY VALVES; relationship between head losses, velocity and disc settings for flow control

is 100 feet and the required flow is 25 cubic feet per second. The water velocity in the pipe is 8.0 feet per second, and the pipe is so short that pipeline friction can be neglected. It can be seen that the valve must be 32.5 per cent open to permit 25 cubic feet per second to pass.

$$H_t = 100 - \frac{8^2}{2g} = 99 \text{ ft.}$$

In this equation, $\frac{8^2}{2g}$ is the velocity head and represents the kinetic energy of the moving water column.

Line "b" represents the same conditions, with the exception that the pipeline friction cannot be neglected because the length of the pipe is 2,000 feet. The head loss for a pipe of 24-inch diameter of this length, manufactured of plate steel, and a water velocity of 8 feet per second is approximately

$$H_p = 0.02 \times \frac{2{,}000}{2} \times \frac{8^2}{2g} = 20 \text{ ft.}$$

With only 100 feet of static head available, the head loss past the valve disc cannot be more than

$$H_t = 100 - 20 - \frac{8^2}{2g} = 79 \text{ ft.}$$

The chart shows that a head loss of 80 feet and a water velocity of 8 feet per second requires an opening position of 34 per cent for the disc.

With the help of the chart it is possible to calibrate the disc position indicator for flow, as well as for disc position, and thus facilitate flow regulation.

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POSITIVE, MECHANICAL RETENTION makes rubber seat truly field replaceable. No dependence on glues, cements or vulcanizing . . . no chance for liner "blow out."

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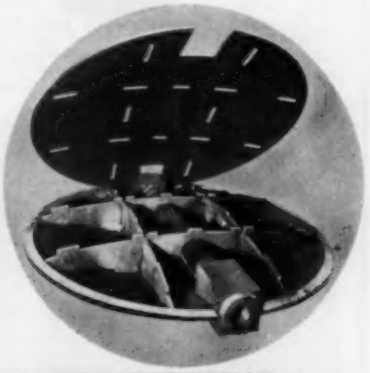
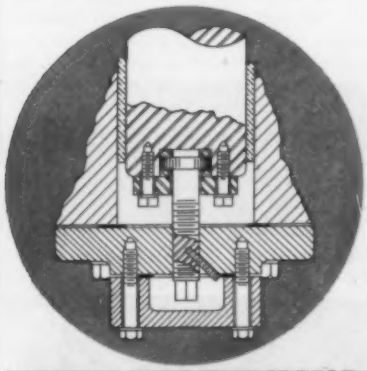
that make PRATT VALVES



CONSERVATIVE DESIGN of entire valve, typified by rugged internal ribs in this fabricated disc—tubular shaft housing to prevent disc flooding.



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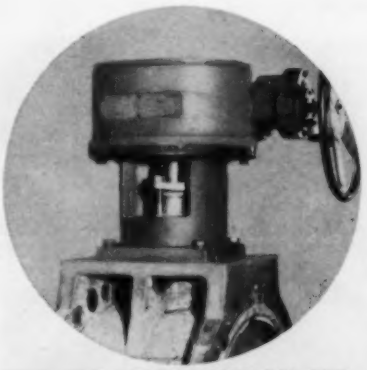

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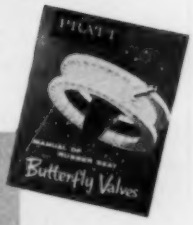

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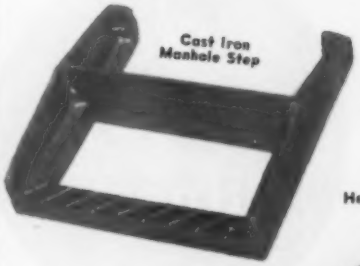
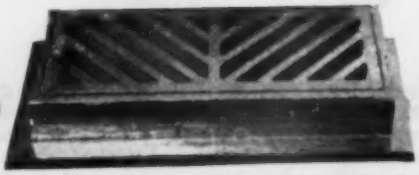


Cast Iron Manhole Step

VALVE
Heavy tapered body

BOXES
Deep cover

DRAINAGE or INLET GRATES
with Frames
bottom flange type



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Clarksville, Tennessee

Modernized Meter Reading

by PAUL WEIR

General Manager, Atlanta, Ga., Water Works

ON JANUARY 1, 1952, the corporate limits of the City of Atlanta were extended from 37 to almost 130 sq mi. Portions of the newly annexed area had been previously serviced with water from the Atlanta system, but many wells also served this area.

A five-year expansion program, now in its last year, was instituted to extend water service to the new area. But one of the most difficult jobs encountered dealt with the monthly meter reading of some 110,000 accounts. Most of the zones in the original city area were read by meter readers on foot, but the expanded limits made it necessary to motorize many of the new routes. About 15 meter readers daily read between 300 and 450 meters each.

The expanded areas brought on an entirely new problem: scattered surburban homes on large lots, and the greater distances between meters. The meters are set as near as possible to the curb line in front of the location to be served, but the net walking distance of the new routes was still increased from two to three times the former ones.

A committee headed by T.H. Bird, the Office Manager, was formed to investigate and recommend improved procedures for handling these routes. Large dairy firms who had the problem of delivering milk in many of the same areas were contacted, but the stand-up type dairy or delivery truck did not lend itself to our needs. Specifically, the hazard of the driver being thrown out of the truck should it hit an obstacle while the operator drove in a standing position did not meet our safety requirements. We next considered removing doors from a ½-ton truck and placing a long safety handle or bracket at the point where the door was previously hinged. This helped somewhat, but still did not reduce the time consumed in entering and leaving the truck when reading the meter. It was next decided to use fluid transmission ½-ton pick-up trucks. This arrangement materially reduced the operating costs, repairs on the clutch, brake, etc., but still did not entirely eliminate the human problem.

In the old days, the inspectors used to ride motorcycles. The "new look" for this type of transportation has been satisfied by the motor scooter. This equipment was carefully investigated, but it did not suit the purpose either. It was not an all-weather vehicle, and every time the operator read a meter the motor scooter had to be parked.

Then a three-wheeled all-weather motor scooter was discovered. This equipment was borrowed for demonstration, and proved so successful that two units were purchased. Others will probably be added to the fleet each year, since about one-half of the routes are now motorized.

Some of the outstanding features of the three-wheeled motor scooter (see photograph) are as follows: It has a small enclosed cab on a three-wheeled chassis. This cab affords all-weather protection to the meter reader and the rear compartment enables him to carry an additional meter reading stick and other equipment to clean out meter boxes.

The scooter is painted in Atlanta Water Works' contrasting colors (blue and white with red wheels) affording the operator greater protection from passing traffic. It has the same gear shift as a car and the clutch is of a type that makes it possible to leave the vehicle in gear and put on the emergency brake while reading the meter. To proceed, the emergency brake is released and gas is fed to the unit.

The motor scooter can be mounted or dismounted from either side without opening a door or stepping up or down. It has a 5-hp motor, giving a top speed of 35 mph and about 50 miles to the gallon of gas. It is manufactured by the Cushman Motor Scooter Company.

THREE-WHEELED motor scooter simplifies curb meter reading

NEPTUNE METER COMPANY

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TRIDENT WATER METERS

. . . Job Tested Ten Million Times

For over 50 years, more Trident meters have been purchased than any other make. Most of these . . . even the oldest . . . are still running accurately. This long serviceable life means lower amortization, obsolescence and replacement costs.

Trident meters have long led the field in design improvements, and today are the finest, most modern meters available. Every improvement has been made to fit all older Tridents. This is one of Trident's biggest advantages.

A planned schedule of testing and repair with Trident meters gives you a continuous program of meter modernization . . . at far less cost than scrap-and-replace methods. Repairs take less time, too, aided by Trident's extreme simplicity. A moderate stock of only the *latest* parts services *all* your Tridents. You waste no time searching or waiting for parts for old meters. Trident parts are *always* available. Your repair men have no obsolete models to learn. If they can repair one Trident, they can repair all . . . efficiently, economically.

TRIDENT METERS FOR DOMESTIC SERVICES IN COLD OR WARM CLIMATES

Trident meters combine fine-instrument construction with the inherent high accuracy achieved only in disc-type, positive displacement water meters. Accurate at all rates of flow within normal test flow limits and remarkably sensitive to small flows.

Trident Frost-Proof Meter embodies the original frost-proof meter feature. If the water freezes and expands, the cast iron bottom cap breaks, relieving the working parts from strain. The bottom cap can be replaced at very nominal cost. For warm climates, the Trident Split-Case Meter is recommended.

Among exclusive features for long accurate life are: Gear train is fully oil-enclosed, including the stuffing box, to isolate vital parts from abrasives, turbulence, corrosive elements, and to provide permanent lubrication. Anti-friction thrust roller absorbs disc thrust, making the Trident virtually immune to disc breakage. Heat-proof, hard rubber bushings in gear train and register are interchangeable. Sand ring keeps abrasive material out of working parts. Materials are corrosion-resistant, with special materials for unusual corrosion problems.

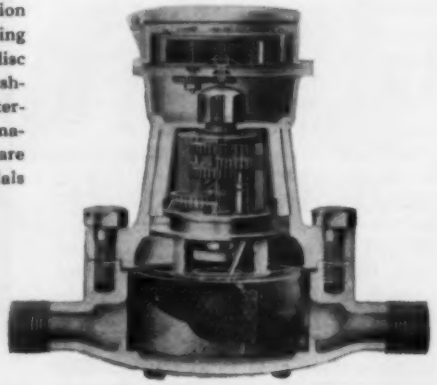
Easy to service and repair . . . makes big savings in meter costs over the years. Register has no screws. Chamber is snap-joint. Disc is in three parts, easy to adjust. Guide pins, slots, etc., assist in assembling meter properly.

Trident Frost-Proof Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
⅝	10¾	7½	5½	9	1¾	20
⅝ x ¾	11½	7½	5½	9	1¾	20
¾	15	9	6	9	1¾	30
1	26	10¾	9⅝	9¾	2	50
1 x 1¼	26	10¾	9⅝	9¾	2	50

Trident Split-Case Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
⅝	9	7½	5	8	1	20
⅝ x ¾	9½	7½	5	8	1	20
¾	12	9	5⅝	8⅝	1⅞	30
1	20	10¾	7½	9	1⅝	50
1 x 1¼	20	10¾	7½	9	1⅝	50

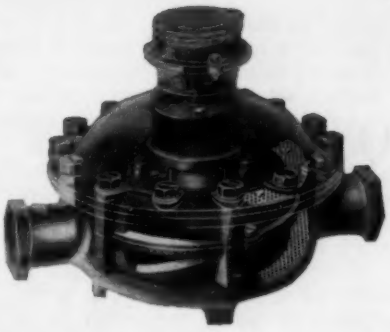


NEPTUNE METER COMPANY

STYLE 3 TRIDENTS FOR MEDIUM RATES OF FLOW

A disc-piston meter for commercial and other installations requiring medium rates of flow larger than household consumption, but not great volumes. Also excellent for "battery" settings where preferred for metering wide flow ranges. In addition to sensitivity on low flows inherent in disc meters, it has the Trident oil-enclosed gear train, heat-proof removable bushings in register and gear train, interchangeable parts and other Trident features which give it sustained accuracy and low maintenance cost. On 1½" and 2" sizes, a "delivery adjustment" can be regulated in relation to line pressure to prevent racing.

These two sizes of Style 3 Meters do the work of any compound meter of equivalent size and, being simpler, they do it with less cost for maintenance and repair.



Trident Style 3 Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	36	12⅝	10	10⅝	2⅝	100
1½ Flge.	40	13	10	10⅝	2⅝	100
2 Scr.	58	15¼	12 3/16	11¾	3⅛	160
2 Flge.	61	17	12 3/16	11¾	3⅛	160
3 Flge.	105	24	16 7/16	17⅞	3⅝	300
4 Flge.	257	29¼	22 1/16	20⅝	4⅜	500
6 Flge.	589	36¾	29	25⅞	5⅞	1000

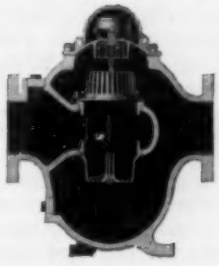
CREST METERS FOR BULK WATER DELIVERIES

For "bulk" water deliveries at periodic or continuous high rates of flow—i.e., where mains deliver water to adjacent townships; hydraulic elevators, cranes, pile-jetting apparatus, etc., the Crest Meter is recommended. Of the velocity type, a turbine is rotated by the water at a speed directly proportional to rate of flow. Among features is the hollow hard-rubber turbine revolving on agate bearing, resulting in minimum friction, maximum sensitivity, sustained accuracy. Standard Trident register and gear train features. All parts interchangeable.

Trident Crest Meters

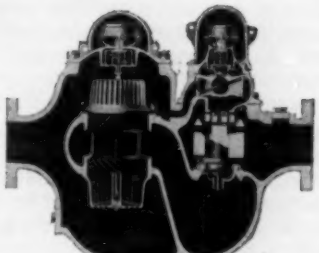
Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	65	12¾	8½	16¼	6⅜	100
1½ Flge.	65	13	8½	16¼	6⅜	100
2 Scr.	83	15½	8⅞	16⅜	6⅛	170
2 Flge.	85	17	8⅞	16⅜	6⅛	170
3 Flge.	250	24	13⅝	27¼	13¼	400
4 Flge.	260	24	13⅝	27¼	13¼	700
6 Flge.	300	24	14⅝	28⅝	14¾	1600
8 Flge.	500	26¾	17½	30¼	15¾	2800
10 Flge.	800	30	26¾	29¼	13⅞	4400
12 Flge.	1200	36	30½	34⅞	16½	6400
16 Flge.	1950	42	36½	40⅞	19¾	12400

**Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications*



COMPOUND METERS FOR WIDE WORKING RANGES

Use this Compound Meter for services with a maximum demand beyond the range of equivalent disc meters—yet with the probability of occasional small rates of flow. Accurate over a wide working range. Measures high rates of flow through a Trident Crest Meter unit and small flows, which cannot be recorded accurately by the Crest, through a Trident Disc Meter unit. In addition to the standard Trident features of both these meters, a specially constructed valve automatically directs the water to the proper unit, depending on rate of flow. Single cast iron casing. All parts interchangeable.



Trident Compound Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	460	33	13⅝	27⅛	13¼	320
4	475	33	13¾	27⅛	13¼	500
6	685	36½	14⅝	28⅝	14¾	1000
8	970	42	17½	29⅞	15¾	1600
10	1500	45 7/16	20⅝	29⅛	13⅞	2300

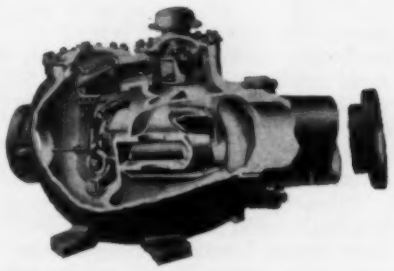
PROTECTUS METERS FOR FIRE SERVICE LINES

Designed for fire line use where both high and low flows occur, and loss of head is an important factor. Meets such requirements with (a) accuracy on all flows and (b) low loss of head plus reliability of operation, satisfying both Water Works officials and Underwriters. Measures low flows through a Trident Disc Meter unit. Large flows are measured proportionally by a Trident Crest unit. Water-way is clear, unobstructed. Both units have standard Trident features which insure accuracy, long life and low maintenance cost.

Trident Protectus Meters

Size In's	Wt. Lbs.	Lgth. In's Incl. Incr.	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	700	64⅜	22¾	21½	8	400
4	900	67	24	24⅜	8	700
6	1600	83⅞	29	27½	10	1600
8	2250	89¾	32¾	30⅞	11¾	2800
10	3400	98⅛	38½	37⅝	14⅝	4375

**Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications*



NEPTUNE METER COMPANY
New York 20, N. Y.

See Page R-174 for Branch Offices and Factories

Meter Maintenance Increases Revenue

by M. O. HAZLETT
Sales Repr., Neptune Meter Co., Boise, Idaho

ONCE you have meters in your water system, proper meter maintenance is a logical step. I think you will agree that if meters are worth installing in the first place, they are worth keeping at top efficiency.

There are two major phases in water meter maintenance. One is the problem of testing them; that is, to see at just what level of accuracy they are performing. The other major aspect of maintenance is the problem of repairing them so they will operate properly.

There are many details involved in both these phases of water meter maintenance. Before discussing them, I would like to enumerate some of the reasons for maintenance. As you know, any mechanical device is subject to wear and requires a certain amount of care and service. Water meters are no exception. Today most water system operators are no longer taking it for granted that once meters are installed, the problem of accurate recording of water delivered is solved. Of course, we have all heard of cases where meters have functioned for 30 or 40 years without stopping, but experience has led the water works industry to appreciate that meters should be checked for accuracy at intervals between every five and ten years.

If a meter has not stopped after many years of service, it may still have suffered from wear. Even the best made meters, designed and manufactured according to the highest standards, can in time be expected to show the results of use.

Basic Reasons for Maintenance

The basic reason for proper maintenance is that of fairness. If a meter is not functioning properly because of wear, it results in under-registration. And this means that some consumers are, in effect, getting the equivalent of a reduction in their rates ranging anywhere from 5 to 50 per cent. It also means that the rate approved by the city council or the state utility regulatory body is not actually being realized.

Primarily, however, the water system itself suffers from the unfairness that results from under-registration caused by improperly maintained meters. The injustice is done to the men who operate the water works, because the system does not actually receive revenue for all the water it produces, treats and delivers.

Realization of the importance of complete and accurate meter registration is one of the main problems in water distribution. The percentage of accounted-for water is directly affected by accurate registration. This occurs because excessive loss of water is corrected by the detection and repair of leaks in services, hydrants, toilets and other fixtures.

Experience has shown that systems which suffer from extremely high per capita use benefit from accurate registration of water delivered. In the final analysis this results in saving in production, purification, and distribution costs and in many cases contributes to increased revenue.

Only by accurately measuring the water delivered against that consumed can the leakage or waste within the system be held to a reasonable limit. An interesting series of tests conducted at Hartford, Conn., indicated that in houses equipped wtih tank toilets 27 to 50 per cent of the total amount of water used was at rates less than one gallon per minute. Obviously, it is vitally important that meter maintenance be carried to such an extent that accuracy is preserved well below the one gallon per minute rate.

Frequency of Meter Testing

To determine whether a meter is registering with accuracy calls for tests to be made. Tests are generally made before new meters are installed or after old ones have been repaired. But the problem that comes up in periodic testing is the problem of frequency. "How often should water meters be tested," is the question that comes up when thought is given to a meter testing program.

In many states the utility regulatory bodies have set arbitrary limits that range from 5 to 10 years. This refers to the ⅝-inch residential size meter which is in most common use. In some cases this limit is set on total registration figures rather than on a time limit, such as 100,000 cubic feet on the ⅝-inch meter.

Actually, the determination of frequency of meter testing depends on local conditions. Various factors enter into this problem. Water supplies differ materially in the character of the water, and the effect of various kinds of water on meters varies greatly. Water pressure may also be a contributory factor affecting the functioning of meters. While Oregon has a rule requiring testing every three years, the average for other states is either five or ten years for those states that do have a rule. And in a few cases the rule provides for testing every seven or eight years.

The selection of a particular cycle depends on the results of experience in each local situation. Accurate records of meters tested, together with the costs of parts and labor involved, will help determine the frequency finally adopted.

In addition to the factor of the quality of water which differs in each system there are other elements that make it virtually impossible to set universal rules in the field of meter maintenance.

Cost of repairs, which includes labor, transportation of meters from homes to the shop, and the efficiency of different systems are all factors that enter into the picture. And they are all factors that vary not only from state to state, but from town to town in any particular state.

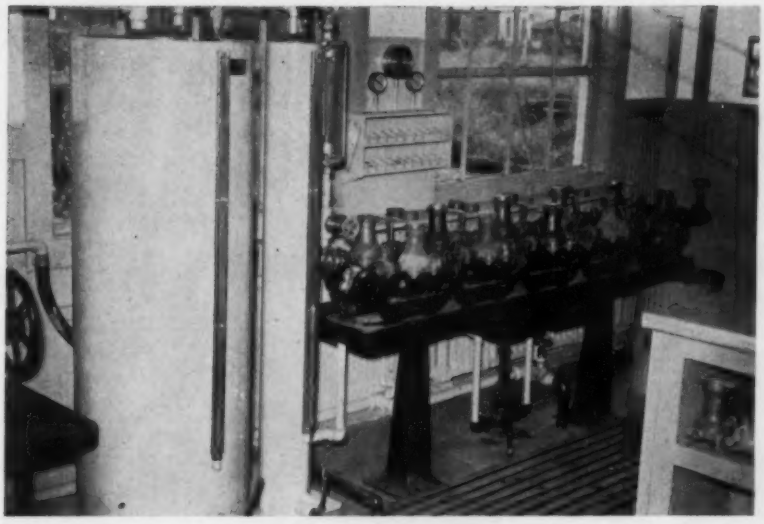
The Meter Maintenance Program

Two general rules that apply to the problem of whether or not it is worthwhile to set up a maintenance program can be cited here.

One rule, less complicated than it appears, states: "In any period of time the highest net revenue from a metered water system is received when the cost of meter repair and maintenance just equals the loss of revenue if such work is not done."

"Highest net revenue" means total collections less meter maintenance and repair. "Period of time" is any period of years, during which all meters have been in the shop at least once.

Another rule (stated by George Sopp, a nationally known expert from the Los Angeles Department of Water and Power) expresses the same thought in another way. Here is what it says: "It is economically advisable to remove a meter for test and overhaul when the average an-



CHAMPAIGN, ILL.—Test bench of meter shop where ten residential-size meters can be tested simultaneously

nual cost of such removal and overhaul is equal to the average annual loss of revenue because of the decreased efficiency of the meter."

After frequency, the problem that comes up most often in meter testing is the rate of flow at which tests should be made. Available reports show that tests are conducted at ⅝-inch or ⅝ x ¾-inch at 20 gpm, ¾-inch at 30 gpm, etc., depending on size (1 or 2 gallons per minute) and at a rate of ¼ gallon per minute.

All testing recommendations call for tests to be made at ¼ gallon per minute, because of the large volume of water that is consumed in the average home at the low rate. Then too, it must be kept in mind that drips and small leaks are generally at such low rates of flow that they will not register accurately or at all on any but sensitive meters.

The importance of low-flow testing cannot be stressed too much, since the great majority of domestic water meters are used in services where small flows, one gpm or less, predominate; these small flows make up a total of as much as 50 per cent of total volume of water consumed.

The meter is often called the cash register of the water works industry. A cash register that is inaccurate in recording small denominations would be objectionable in a retail shop and, similarly, in retailing water the importance of low-flow accuracy is apparent when it is recalled that a large percentage of the consumption of the average water utility is in the retail shop classification.

The first step in starting a program of meter maintenance is to remove either the oldest meters from continuous service, or those meters that have the highest total registration. In this way, the system would benefit the most by getting its oldest meters removed from service, inspected, overhauled and tested.

The Meter Testing Installation

Now, before turning to a few comments on repairs something should be said about the equipment and facilities needed by the average small-sized system. The first requisite is to supply adequate space. This should be sufficient to house equipment properly without crowding. There should also be enough room for storage of repair parts as well as new and repaired meters.

In regard to the test branch, it is well to consider, even for the smallest type of shop, the advantages of a multiple testing unit where from four to ten small meters can be tested at one time. Again let me quote Mr. Sopp (Los Angeles Department of Water and Power) who stated that "an appreciable saving in time and effort can be gained [by multiple testing] over that of a single meter test bench operation.

Equipment for the test bench should include a 10-cubic foot or 100-gallon, and 1-cubic foot or 10-gallon, test tank and a test flow indicator. The low-flow indicator is generally considered essential to the proper control of the rate of flow passing through the meters during the testing procedure.

Other equipment for shop work should include some equipment for cleaning of meter cases; at least two adequate and sturdy work benches, preferably metal topped; one small bench for gear train and register repairs; a deep-set sink near the bench for washing parts; buffers; miscellaneous hand tools; dies; drills; etc. Mostly, this equipment is available at local hardware stores, or from meter manufacturers.

A portable meter should be available to prove to the consumer as well as yourself that an installed meter is running accurately. Portable meters usually can be connected to a sillcock or outside faucet, in order to check the meters in the pit or box. If you cannot afford to buy a portable, order a new meter from the manufacturer and state what you are going to use it for. I do not recommend this as a means of testing, as any error here through wear or dirt and sand will throw the service meter off. This field testing method does help public relations, and if the service meter does not register close to the portable meter it can be taken in and tested on the bench.

Steps in Meter Repairing

It must be recognized that the demonstration of repair procedures is the best way to understand that meters can be effectively repaired without complicated equipment.

The steps called for in meter repair work, after the meter has been tested, begin in careful disassembly of the meter. Particular care should be given to the disc and chamber, since it is absolutely essential that they be properly repaired if high accuracy is to be obtained.

The disc chamber should be carefully cleaned. Special attention should be given to the gear train. All gears, spindles and bushings should be checked for wear. We recommend the gear train be disassembled whenever a meter is being repaired, if needed, the new parts should be added, and new bushings should be installed, as well as screws holding the train together. If the oil-enclosed type is used, individual gears may be substituted.

The stuffing box and register need careful attention, to assure that no binding action will cause accuracy to fall off, especially at the low flows. After all parts of the meter have been given necessary attention, and the meter is reassembled, testing after repair is necessary proof of workmanship. If the meter does not run accurately, then it was not repaired properly. Standards for meter performance after repairs are generally the same as those for new meters.

Payment for Meter Repairs

One of the questions that frequently arises in connection with a meter maintenance program is "Who

KENOSHA, WISC.—Meter testing and repair shop layout featuring adequate space and plenty of light

should pay for the repairs?" This is an interesting question which has been answered more or less similarly by the operators of many water systems.

Typical of how this problem has been solved is a report from Kalamazoo, Michigan. Here is what Earl E. Norman, the manager of the City Light and Water Utilities reported:

"We operated under the plan of charging customers for meters and repairs and found that there could be no worse plan, relative to public relations. An extra charge of any kind, regardless of how justified it may be, irritates the public. We have, therefore, eliminated extra charges entirely.

"We feel that a public utility, whether it sells water, gas, electricity, or steam, and whether it is privately or publicly owned, should charge for the commodity sold, at the meter, and should make no other charges. We believe it should maintain at its own expense the metering devices and the distribution system up to the point of measurement."

Another aspect of the repair costs involved relates to the occasions when the customer is at fault. In many systems the customer, in such instances, is charged. Typical of this attitude is the procedure reported by the Board of Water Commissioners in Detroit. Here is what they say:

"On 2-inch and smaller meters we make all repairs, except those caused by customers's carelessness or lack of protection, such as frozen meters, recurrent damage by hot water, breakage by actions of owners or tenants, etc. We think this is equitable."

Experience with Meter Maintenance

In conclusion, I would like to report some experiences of maintenance programs in various parts of the country. Proven results are the most convincing arguments in any field, and they apply particularly in the water works industry.

Three years ago, the town of Winchester, Virginia, initiated a program of meter testing and repairing. At the last report, half of the town's 4,200 meters had been taken out and tested, overhauled and replaced.

This is what S. H. Reeves, superintendent of Water and Sewers had to say: "Our records show the program has increased revenue, in those areas where the project has been completed, by more than 14 per cent. Not only is our program paying for itself, but it is also substantially increasing the city's water revenue." That report is from a town of only 14,000 population.

A similar experience is reported from Green Bay, Wisconsin, a town of 46,000 population. A meter survey was conducted between the years 1937 and 1940, during which time 10,072 meters were repaired at a total cost of $21,115.

In 1936, before the survey started, 64 per cent of the 1,064 million gallons of water pumped was accounted-for, and $264,877 was received in revenue.

In 1940, the year the survey was completed, 81 per cent of the 1,066 million gallons pumped was accounted-for and $301,245 was received in revenue. These figures show that almost the same amount of water was pumped during the year before the survey started as was pumped the year it was completed. The same rates were in effect during both years, but the revenue received by the department was $36,367 greater in the year the test and repair program was consummated.

Thus, we see that in this Wisconsin city, the increased revenue during that one year more than paid for the cost of the entire meter test and repair program.

To sum up, it should be emphasized that this type of experience has been reported over and over again. Reports from all parts of the country confirm that effective maintenance procedures result in both curtailed water waste and in increased revenue for the water system.

Incentive Pay Plan for Meter Shop Output

Philadelphia first to adopt incentive pay plan as feature of meter-shop reorganization on a production line basis.

by G. E. ARNOLD

General Superintendent of Water Works at Philadelphia, Pa.

PRIOR to 1918, there were few water meters in Philadelphia. At that time it was decided that metering should be initiated, and an ordinance of the City Council in that year required that all new construction built in Philadelphia after that date be equipped with a meter on the water service line. Later, another ordinance required that all commercial and industrial establishments be metered regardless of age. By 1952 there were more than 500,000 active water services in Philadelphia of which about 320,000 were metered and 180,000 were unmetered. All of the unmetered services were in residences older than 1918 and were scattered throughout the city.

During 1952 the decision was made to complete the metering of the entire city which meant the installation of water meters on the 180,000 water service lines then unmetered.

At the time the decision was made to complete the metering of the city, it was decided that all water meters would thereafter be installed or removed only by Water Department employees. Prior to this time meters had been installed by plumbers with the Water Department employees engaged only in removal or reinstallation when meters required repairs. This decision was not popular in some areas and resulted in a law suit.

The suit was filed against the City officials, particularly the Water Commissioner, contending that the City and the Water Department were depriving plumbers of business enterprise by insisting that consumers buy meters only from the City, and that the Water Department make the installations, contending that the requirements of the Water Department regulation on universal metering were discriminatory and that the City was violating the Constitution of the United States and that of the Commonwealth of Pennsylvania.

The trial occupied several days of testimony and became quite involved. The Lower Court handed down its decision on June 17, 1954 reciting thirty findings of fact, all thirty of which were favorable to the position of the City and the Water Commissioner, as defendants in the case.

The decision of the Lower Court was appealed to the State Supreme Court and was heard by the high court in January, 1955. The State Supreme Court handed down a decision upholding in full the findings of the Lower Court and Universal Metering was resumed. Our schedule calls for completion of the metering of the entire City by June 1, 1957.

This case for reference purposes is listed as 2D&C2d761. It was affirmed in 382, Pennsylvania 399.

The Meter Repair Program

An entirely new concept of water meter repair was instituted about

CONVEYOR carrying repaired meters from assembly benches to the test benches.

METER CHECK-OFF LIST		WATER DEPARTMENT METER DIVISION
METER		DATE
	S. B. BEARING	
	BOLTS AND NUTS	
	BOTTOM	
	REGISTER BOX ONLY	
	REGISTER BOX COMPLETE	
	TOP CASE	
	CHAMBER	
	SPLIT COLLAR	
	REGISTER BOX COVER	
	REGISTER CUP	
	DIAPHRAGM	
	DISC	
	REGISTER FACE	
	GASKET	
	REGISTER CUP GASKET	
	COMP. GLAND	
	REGISTER GLASS	
	CHAMBER INSERT	
	CLAMP NUT	
	S. B. NUT	
	S. B. BEARING NUT	
	S. B. CLAMP NUT	
	REGISTER BOX PIN	
	REGISTER	
	SPLIT CONTROL RING	
	THRUST ROLLER	
	SCREEN	
	SCREWS (REG. CAP)	
	SCREWS (CHAMBER)	
	SCREWS (CHAMBER HOLDING)	
	SCREWS (REG. CUP)	
	SCREWS (DIAPHRAGM)	
	SCREWS (HEX TRAIN)	
	SCREWS (TRAIN)	
	DISC SPINDLE	
	S. B. SPINDLE	
	TRAIN	
	WASHER	
	S. B. BEARING WASHER	
	REGISTER SPRING	

METER check-off list used by the meter inspectors for ordering replacement parts

STOCK ROOM, with clerk filling meter inspector's order by placing replacement parts in meter pan

three years ago in Philadelphia and has resulted in a vast increase in the number of meters repaired, without increase of the number of personnel required and at a considerable reduction in overall cost.

In 1952 there was a large back-log of unrepaired meters still in service on consumers' premises in Philadelphia. These meters totaling about 30,000, were supplemented by an additional 5,000 meters in the Meter Repair Shop awaiting repairs. These meters were being repaired at the rate of about 400 a week. The customary procedure, then, was for each repairman in the shop to service a meter in its entirety by himself; including dismantling, cleaning, and repairing.

In 1952 a firm of industrial consultants was employed to review the operation of the Meter Shop and to recommend improvements. As a result of their survey, the Meter Shop was re-organized, new equipment purchased, a new procedure established and the employees placed on an Incentive Pay Plan. This is believed to be a complete innovation in compensation of municipal employees, but it has proved well its worth in Philadelphia.

Replacement of Meter Parts

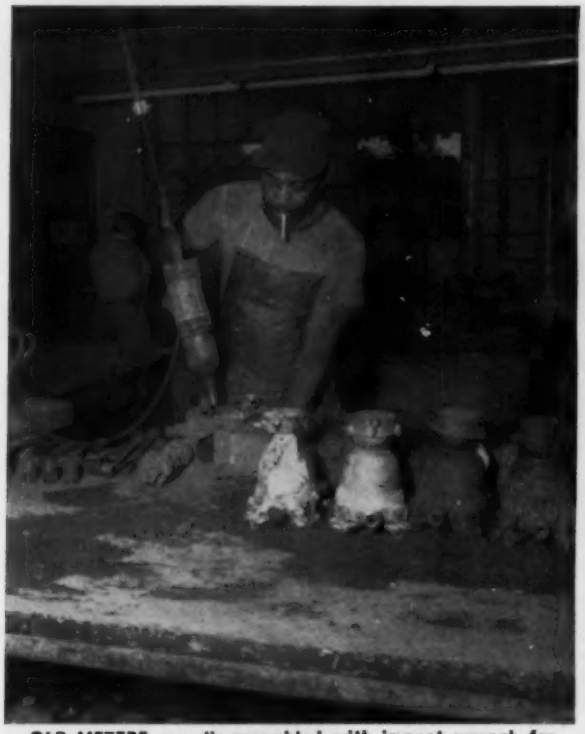
Now, as the meters come into the Repair Shop, the necessary records are taken and then the meter moves to a break-down bench where the main case bolts are removed with a power wrench known as an impact wrench. Following this, the meter is disassembled and all of the parts placed in a square steel pan about 2" deep and 15" square. Portions of the meter are then given an acid dip to remove scale and grease, after which the clean parts are rinsed and then the meter and parts go to an inspection bench. Here the inspector carefully examines each part of the meter to determine whether it can be reused or must be discarded. As he discards a meter part he makes a mark on the checkoff sheet, reproduced herein, and the remaining parts of the meter, with the checkoff sheet, are put in the steel pan and rolled on a conveyor into the stockroom. Naturally, this operation is a very important part of the repair and replacement system. The inspector must be thoroughly experienced and know his business, if new meter parts are not to be wasted or a meter reassembled only to fall short on the test bench and have to be returned for dismantling and re-assembly.

The stockroom clerk uses the checkoff list to place in the pan, a part for each one properly marked on the list. The complete meter with the old and new parts then travels to a window where the men on the repair bench take over the meters for assembly. The stockroom clerk keeps the checkoff lists and totals them at the end of the day for his inventory records.

The Repair and Assembly Bench

The man at the assembly bench put the meters together, gives them a quick water and air test to see that they are operating properly, and then places them again in the steel pans following which they travel on a conveyor to the test bench. All meters are given a thorough test and any meter not meeting the test is returned for correction to the man who assembled it. After test, the meters are rolled on another conveyor to the paint spray booth, where they are given a coat of paint and then placed on racks to be installed in consumers' premises.

In summary, the meters move through the shop on a production line basis. No one has to carry a water meter more than five or ten feet in the shop. They move from one process or location to another by gravity roller conveyors, each meter being kept to itself in its steel pan. Each step in the operation is performed by one man who is especially



OLD METERS are dis-assembled with impact wrench for removing case bolts.

SPRAY PAINTING of repaired and tested meters which move into storage.

trained and qualified for that step. We are currently repairing about 1,400 meters a week in the shop with the same number of employees that formerly repaired 400 a week, and the repair work is being satisfactorily done.

The Incentive Pay Plan

One of the most important developments in connection with the increased production in the meter shop is the incentive pay plan on which most employees work. Time studies were carefully made of each operation and a standard established for that operation. The standard minute is a 60 second minute and each operation receives a credit in seconds and fractions to make up the total amount of work that a man should be able to do in 60 seconds. If he exceeds this basic standard, he receives additional pay for the extra work done, in accordance with the established standards. If a man fails to meet the standard, he receives the standard pay regardless of his deficiency; but if a man consistantly falls below the standard, he is given another assignment or let go. It was this guarantee of the basic wage which brought about approval of the plan by the union.

In determining the standards, consideration was given to the difficulty of the work on different makes of meters—some meters receiving a larger basic standard for certain steps than other makes of meters. Records are kept of each man's operations each day, and the total number of minutes of effective work he has produced during the day are considered in making up his daily wage. Field operations of removing and installing meters, or making minor repairs on the consumers' premises, are also on an incentive pay basis. Credit is given for each operation performed by a field man. For example, he receives a certain credit for a "no-response" when there is no one home. He receives certain credit for removing an old meter and installing a new one, and he receives certain credits for minor repairs such as re-packing a stuffing box. Reasonable driving time is allowed in moving from one job to another. Each installation crew is given a larger volume of work than they can accomplish in one day

REPAIRMAN at an assembly bench.
Note roller conveyor in background with meter in pan.

LARGE METER under test in shop. Incentive pay does not apply in large meter repair and testing for reasons given in text.

so that there is assurance that they have plenty of work to keep them busy during the day. Shop and field inspections are made on a spot-check basis to see that the work is properly done.

The basic pay standards were approved by the Civil Service Commission and have been revised once since they were originally instituted. In some cases, the basic standards were increased and others decreased as a result of operating experience under the new plan. So far as is known, this is the only incentive pay plan in operation in a municipal water system, and it is working satisfactorily. On an average the men earn an incentive bonus, amounting to 20% of their base pay, and the volume of work being done has greatly increased with an over-all reduction in labor costs. To repeat, the work is satisfactory.

Large meters are not handled under the incentive pay plan because of the wide variation between makes and types and the repair work which must be done. Both field and shop employees in handling large meters are in a higher classification schedule and receive higher standard pay. The institution of an incentive pay plan for handling large meters does not appear to be practical.

What it Has Accomplished

All together, the revised schedule and new method of operation has tripled the number of meter repairs made per month in the shop, and has also resulted in a vast improvement in field operations. Within two years after the incentive pay plan was instituted and the new procedure in the shop started, the backlog of meter complaints was wiped out, and today the Meter Shop is practically current with service work.

Prior to 1953 meters had never been brought into the shop except on complaint, indicating that they had either stopped or were leaking or in bad order. As a result, there are many thousands of meters in the system which have never been inspected or repaired. In 1954, a rotation schedule was established under which all meters will be brought into the shop for repair at least once in ten years. It is felt that this rotation schedule wil result in better metering of the water and a definite increase in revenue. Many of the old meters brought in are found to be non-registering at the low flows. Because the meters had been neglected, the cost of repairs is higher than it would be for meters kept in good condition. The labor is very little more in cost, but the parts are running considerably above the average, due to the bad conditions of the meters. We are currently finding that the labor costs for repairing a 5/8 inch meter are $1.75. Before the new plan was instituted, the labor cost for these repairs was $3.50 on the average.

Philadelphia is now completing the metering of the entire city and will very shortly have over 500,000 active metered accounts. The Universal Metering program has been previously described in other articles. The development of the Universal Metering program, together with the re-organization of the Meter Shop and the schedule of rotating meters, has resulted in definite improvement in the over-all metering practice in Philadelphia. Substantial increases in revenue are resulting from the new currently being kept in good repair.

Anyone interested in our meter shop reorganization, or Incentive Pay Plan in the metering program, is invited to come to Philadelphia to inspect our operations and obtain more details than could be given in an article of this length.

Solvent Cleaning of Meters

by ALEXANDER SMOLENSKI
Water Service Supervisor, Hamtramck, Mich.

FEW MUNICIPAL functions are as efficiently administered as that of public water supply. Further economies in that field are difficult to effect. A small but important economy practiced by the City of Hamtramck, Mich., which should be of general interest is its meter reconditioning program.

Water meters, like any other equipment, represent a substantial investment on the part of the city. Too frequently they are an investment that is out of sight and, unfortunately, out of mind. But since the city of Hamtramck inaugurated its modern program of meter restoration, it has realized substantial economies and has immeasurably improved the quality of its reconditioning work. The simple process which we employ first came to the attention of the writer at the AWWA Convention in Chicago, in 1949. Known as the "Kelite Dip Method," it has become our standard method for renovating Badger, Worthington-Gamon and Federal Meters.

The term "dip-method" is an accurate description of the procedure. All cleaning, descaling, brightening, etc., is accomplished solely by dipping the component parts of the meters into successive liquids designed specifically for the job. Since there is no special equipment required, the cost of inaugurating the program in a city the size of Hamtramck amounts to the price of three five-gallon earthenware containers plus the modest cost of the liquids.

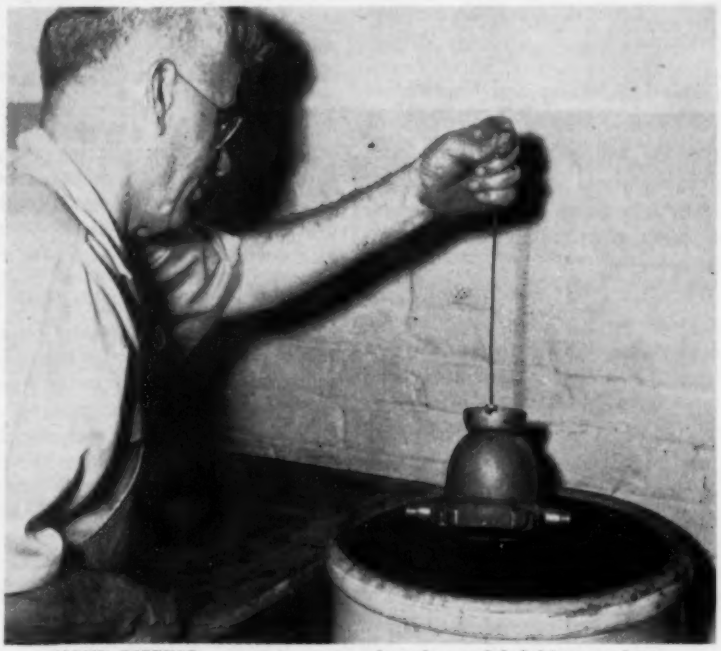
In "dip reconditioning" the first step is the complete disassembly of the meter. Obviously, this operation is required regardless of what method of reconditioning is used. The disassembled meter parts are then placed in a small wire basket and dipped consecutively into the three room-temperature solutions, with hot water rinses between each dipping. Reassembly follows the final dip.

The first dip is for the purpose of dissolving gummy, oily or greasy accumulations. The liquid employed is a commercial solvent known as Kelite Formula 555. Like all the liquids used in the process, it is non-flammable and requires no heat. When used according to directions, it is harmless to all metals used in water meter construction.

The second dip is for the purpose of dissolving the rust and mineral scale deposits so frequently the cause of excessive wear or stoppage. This is accomplished by means of a solution known as Scale-Off.

It will be noted at this point in the process that, while thoroughly clean, the metals have been tarnished by the chemical rust and scale remover. The tarnish is, however, a superficial condition and is readily removed by immersion of the parts in the third and final dip. This last solution, Metal-Brite, has a sterilizing as well as a brightening action. Rinsed and dried, the parts are found to be bright and clean as new—ready for reassembly.

According to the recommendations of the AWWA, water meters should be checked and tested every seven years. A city of 43,300 citizens, Hamtramck requires 7,700 meters to maintain its 100 per cent metered service. This means that we have the routine job of reconditioning 1100 meters a year, *plus* the usual repairs and reconditioning jobs occasioned by failures, stoppages, etc. Such a program would be an involved and costly undertaking for our small community were it not for this new development in cleaning metal parts. With it, however, we have been able to prove that new economies are possible.



HAND DIPPING removes grease, descales and brightens meters.

ENCRUSTED meter (left) is restored to "like new" condition (right).

WATER TREATMENT

WHEN WATER REQUIRES treatment before it can be used for municipal or industrial purposes, the treatment processes are commonly termed purification. The kind of treatment employed in water purification depends on the characteristics of the water and its intended use.

The steps employed in water purification include these unit processes; coagulation, mixing, sedimentation, filtration, disinfection, aeration, absorption, chemical oxidation, ion-exchange, chemical precipitation and stabilization.

Coagulation, Mixing and Flocculation

As the first step in the removal of suspended and colloidal matter from water, chemical coagulants are added. For this purpose chemical handling equipment, chemical feeders and controls are required.

When chemicals are first added to the water, it is necessary to disperse the chemical quickly throughout the water. This action is known as rapid mixing. Slow mixing follows for the purpose of flocculation, that is to cause an agglomeration of colloids and finely divided suspended matter into large flocs which will settle readily.

Sedimentation

Sedimentation or the settling of solids under the influence of gravity, provides for the removal of the suspended and precipitated matter. This treatment takes place in tanks designed to produce the desired flow-through period. These tanks, either rectangular or circular, are equipped with valves, level controls, and devices for the removal of the settled solids.

Filtration

Suspended matter remaining in water after sedimentation can be removed by passing the water through beds of porous material, usually sand. Crushed anthracite coal also may be used. The filter medium (sand or anthracite) is contained in a box like structure with a valve system to control the flow of water and an underdrain collection system.

There are two types of sand filters: slow sand in which the water flows through the filter medium at less than 0.2 gal per sq ft per min; and rapid sand filters in which the flow rate is from 2 to 5 gal per sq ft per min. A third type of filter is the diatomite filter in which diatomaceous earth is mixed with the water and removed on a porous septum.

The removal of suspended and colloidal matters by filters is accomplished in this manner. Particles larger than the pores are strained out, particles smaller than the voids catch on and adhere to sand grains or other matter previously removed. Microorganisms for sticky coatings on sand and attract and hold other particles.

The filter box contains an underdrain system (for filter bottom) above which is a layer of coarse gravel, topped by a layer of sand or crushed anthracite. Valves are used to control the flow of water onto the filter and a controller on the effluent maintains the flow of water through the filter at a constant rate.

When the filter becomes clogged as indicated by loss of head in the filter, it becomes necessary to backwash it. Incoming water is shut off and by proper valving operations, clean water is forced upward through the sand and out to waste carrying with it the impurities and foreign matter that have accumulated in the filter during operation. The length of filter wash period depends on the dirtiness of the filter but 3 to 5 minutes is usually sufficient. Surface washing is sometimes used along with upward wash. Washing operations can be initiated and controlled automatically.

Aeration and Taste and Odor Removal

The purpose of aeration is to improve the quality of water, particularly with respect to tastes and odors. Types of aerators may be waterfall, air diffusers, or spray nozzles.

Other methods of taste and odor removal employ either preventive or corrective treatment. Preventive treatment consists principally of attacking the causes, especially algae control by copper sulfate. Corrective treatment consists of either chlorination or removal by adsorption on activated carbon. The control of odor removal is based on the threshold odor number and its determination.

Softening and Stabilization

Chemical precipitation is involved in both coagulation and in softening. The purpose of softening is to remove unwanted salts of calcium and magnesium. This treatment may be accomplished by the addition of lime or lime and soda ash to the water. Another softening method utilizes ion-exchange and no precipitation.

Waters which contain carbon dioxide or have a pH below neutral or have low alkalinity tend to be corrosive to mains and household services. Lime softened waters sometimes tend to deposit scale. Treatment to overcome both of these tendencies is termed stabilization. Stabilization of corrosive waters is accomplished by pH adjustment, usually with lime. Stabilization of lime softened water may be accomplished by recarbonation with carbon dioxide, by the addition of alum, or by the addition of sodium hexametaphosphate, known as the threshold treatment.

Miscellaneous Treatment

Fluoridation is not really a water treatment process but rather is a process for the adding of a chemical to water supplies, as a carrier, in order to provide a micro-nutrient to the diet of consumers. The purpose of adding fluoride ions to water is based on the observation that children who consume water containing no more than 1.0 mg/L of fluoride ion, have approximately 60 per cent less dental cavities than children who do not drink such water.

Other miscellaneous treatments may include ozonation for disinfection and taste and odor control, demineralization, defluoridation of waters high in fluoride ion, and deoxygenation especially for industrial water supplies.

Seven Years of High-Rate Filtration*

by JOHN R. BAYLIS

Engr. of Water Purif., Div. of Water Purif., Bureau of Water, Chicago, Ill.

A NUMBER of filters in the Chicago South District Filtration Plant are now in their eighth year of continuous operation at rates in excess of 2 gpm per square foot of filter surface. On Feb. 1, 1948, eight of the 80 filters then in operation were set at a rate of 4 gpm per square foot by adjustment of the filter rate controllers. Nine months later, four of these eight were reset at a rate of 4.5 gpm, and two additional filters were set at 5 gpm, making a total of ten filters operating at high rates. The purpose of this paper is to present a summary of operational data for these filters for the 7-year period beginning in 1949. (Since neither the number of filters nor their rates remained constant during 1948, the data for that year are not included in this presentation.)

The experience with these filters through February 1950 has previously been described by the author[1]. The paper included a number of tables comparing average monthly rates and two tables indicating the results of daily tests of turbidity and floc volume for the 5-gpm filters. The opinions and conclusions expressed in 1950 are as valid today as when written. Each additional year's experience provides added confirmation of the accuracy of the data. Since that time, monthly averages have been tabulated annually in the plant's publication, *Pure Water*. In the present summary, however, only yearly averages are supplied in most of the tables.

The time in which a filter can be maintained in service is important. This is especially true of high-rate filters, as they require more filter washes per day. The entire washing process—washing the filter and closing the backwash valve, opening the influent valve to allow the filter tank to fill with settled water, and opening the effluent valve—requires about 15 min. For average filter runs of 24-hr duration, the time out of service amounts to 1.04 per cent. This is not quite correct, however, for 15 min or longer may be required to drain the water above the sand bed almost to the level of the sand, as is customary practice. When the influent valve is closed, the water level will begin to decline. If the loss of head for a given filter is 8 ft, and the available loss of head is 10 ft, the filtration rate will start to decline as soon as there is no longer sufficient head to maintain it. At the end of the draining-down period the filtration rate may be less than half what it was at the time the influent valve was closed. The volume of water filtered during the draining-down period may be only three-fourths of that which would have been filtered if the rate did not decrease. At a rate of 5 gpm, this is the equivalent of a loss of 3.75 min. As it would require considerable time to take this loss into account, it was not done. The time a filter is out of service, as indicated in Table 1, is based entirely upon the filter operator's record, which shows the time the effluent valve was closed and the time it was reopened, but does not account for the reduced rate. The time the filter is in service would be about 0.5 per cent less than the figure given in the table. Thus, the effective time in service, instead of averaging 98.9 per cent for filters operated at 2 gpm, as indicated in Table 1, would be close to 98.4 per cent.

Length of Filter Run

Table 2 shows the annual average filter runs for the period 1949-54.

TABLE 1

Time in Service

Year	2-gpm Rate*	4-gpm Rate (4 Filters)	4.5-gpm Rate (4 Filters)	5-gpm Rate (2 Filters)
	Time in Service—per cent			
1949		98.0	97.2	96.5
1950	99.0	98.0	97.8	97.0
1951	99.1	98.3	97.9	97.2
1952	99.0	97.8	97.7	96.0
1953	98.8	98.0	97.4	96.9
1954	98.6	97.5	97.5	96.9
Avg	98.9	97.9	97.6	96.7

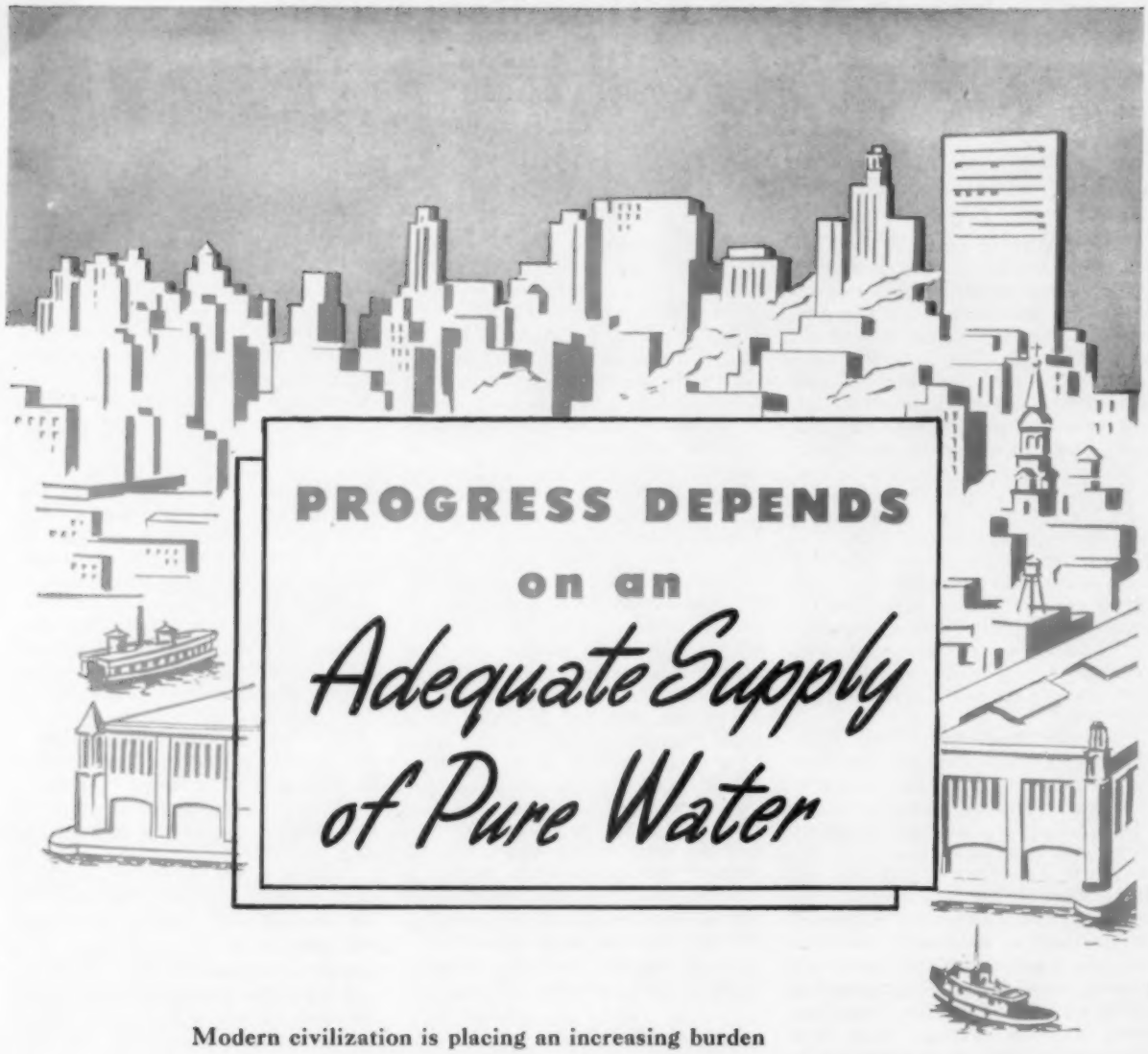
* Four filters recorded for 1950-52; two for 1953-54; none for 1949.

The averages for the entire 5-year period do not vary so widely as the monthly averages for those years. Daily averages (as indicated by the maximum and minimum columns in Table 3) vary still more widely than the monthly figures. For the period shown (January 1953-October 1955), the runs have ranged from 4.7 hr for the day of shortest run to 57.2 hr for the days of longest run. Most of this disparity may be attributed to the daily variation in both number and kind of microorganisms present. A second factor, in this regard, is that one settling basin was out of service for much of the period November-April of each year, decreasing both mixing and settling time by a third during those periods. (It was necessary to remove a single settling basin from service each year in order to change the raw-water meters from the venturi tube type to flowmeters.) It is not recommended, therefore, that the reader attempt to evaluate too closely any but the average-run data in Table 3.

Analyzing the figures in Table 2 more closely, it may be assumed that the amount of flocculated material going to a filter operating at 4 gpm is twice that of a filter operating at 2 gpm. The amount going to filters operated at 4.5 and 5 gpm would be proportionately greater. Assuming that the clogging rate is in proportion to the amount of flocculated matter going to the filters, one may estimate that filters operated at 4 gpm will have runs approximately half as long as those of the 2-gpm filter; that is, about 14.4 hr, as the runs on the 2-gpm filters averaged 28.7 hr. Following this logic, the runs for the 4.5- and 5.0-gpm filters would be 12.8 and 11.5 hr, respectively. These figures are not far from the runs actually recorded over the 6-year period.

This simple comparison of the actual and computed filter runs does not take into account all of the facts. Filters were washed after 2 days of operation, regardless of loss of head. There were periods of short duration in which the 48-hr limit determined the time to wash. If the filters had been allowed to continue in service

* Reprinted from JAWWA, Vol. 48 No. 5, p. 585 (1956)



Modern civilization is placing an increasing burden on those responsible for supplying greater and greater quantities of pure water for home, recreation, and industry.

The dependability of the mechanical equipment charged with the responsibility of unfailing operation is a consideration which continues to pay big dividends over the years.

You can depend on Roberts Filter.

MECHANICAL EQUIPMENT
BY
ROBERTS FILTER MFG. CO.
DARBY, PENNA.

at all times until the loss of head reached 8 ft, the average length of filter run for the 2-gpm filters would have been slightly higher, probably close to 30 hr instead of 28.7 hr. This would bring the computed estimates nearer to the actual lengths of the runs recorded for the 4- and 4.5-gpm filters.

In considering the data for the 5-gpm filters, it must be taken into account that an 8-ft loss of head could not ordinarily be obtained; generally, these filters had to be washed under conditions of 7-8 ft of head loss. Had it been possible to obtain the same loss of head as for the other filters, the average length of filter run for the 5-gpm filters would have been more than the recorded 10.2 hr, probably between 11 and 12 hr.

Another factor must also be considered: the initial loss of head is greater on a high-rate filter than on filters operated at 2 gpm. More precisely, a 5-gpm filter has an initial loss of head about twice that of a 2-gpm filter. At a temperature of 45°F the filters in the South District plant have an initial head loss of approximately 0.6 ft at the 2-gpm rate, and 1.3 ft at the 5-gpm rate. Running the filters to 8-ft loss of head, the lower-rate filter would have an increase over the initial head loss of about 7.4 ft, while the 5-gpm filter would have only 6.7 ft of increase. These factors are mentioned so that allowance may be made for their influence in using the data presented. The loss of head in the rate controller and the filter effluent piping is not great at the 2-gpm rate, yet it becomes considerable at the 4- to 5-gpm rates.

Turbidity and Floc Volume

Because of the work involved, daily turbidity tests were not made on the effluents of all of the high-rate filters—only the 5-gpm filters were sampled. Annual summaries for the 6-year period are given in Table 4. The yearly averages are low, as were the monthly averages used in computing them. During the 6-year period, the laboratory recorded two tests which could be considered objectionable. One of these showed a turbidity of 1.3 ppm on the effluent of Filter 77 in August 1954; the other was a reading of 2.0 ppm on the effluent of Filter 10 in September 1954. In both instances, a note was made on the record sheet that the turbidity was composed of colloidal rather than flocculated material. An insufficient application of the coagulating chemical could have been the cause. No further investigation of the tests was made and there was later no means of checking back to determine the cause. Colloidal turbidity does not ordinarily occur on one filter alone. The outlet water from the plant, tested every 4-6 hr, showed zero turbidity each day of the month for the 2 months in which the two high readings were recorded.

Floc, or coagulated material, is often measured by turbidity tests. A more accurate test, however, is to measure the volume of the floc itself. Where there is considerable floc, this may be done with a centrifuge. When the amount is low, the test is made by comparison with standards of known floc volume. Procedures for preparing floc standards and making tests have been described in detail by the author[2].

The unit "floc volume" is based on the volume of flocculated material in the water: thus, 1 gal of floc in 1 mil gal of water is 1 floc volume. The floc volume is a figure generally about 15 times the turbidity. A water containing 1.0 ppm of flocculated material will have a floc volume close to 15. The relationship, however, is influenced by the turbidity of water before coagulation, and the figure given applies only to low-turbidity raw water (less than 50 ppm).

Table 5 compares the annual averages of the floc volume in the effluents of the 5-gpm filters. The table also gives the maximum day for each year of the 6-year period, as determined by a single daily test.

The maximum floc turbidity for a single test was 5.0, which would represent a turbidity of about 0.4 ppm. The average floc volume over the 6-year period is less than 0.1. This is quite low and indicates a high quality of water. Many filtration plants pass considerably more than this volume of floc in water which is considered to be of good quality.

Bacteria Counts

Table 6 gives the yearly average of coliform bacteria found in water from the high-rate filters. During April 1952, there were a few samples of water that had high coliform counts; these, however, were not confined to the high-rate filters. Investigation disclosed the cause to be in the sample bottles. Because these data tend to be misleading, two averages for 1952 are given: one including the

TABLE 2

Length of Filter Run

Year	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Length of Run—hr			
1949		15.2	12.4	9.9
1950	33.0	17.1	14.7	11.3
1951	36.6	19.6	16.6	12.9
1952	26.1	16.5	14.5	10.8
1953	26.3	12.6	11.3	8.4
1954	21.3	11.6	9.9	8.3
Avg	28.7	15.4	13.5	10.2

TABLE 3

Filter Runs for Years 1953-55
Average of All Filters

Month	1953			1954			1955*		
	Length of Run—hr								
	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.
Jan.	20.0	47.8	10.3	21.4	37.5	14.9	14.0	37.5	8.8
Feb.	36.6	53.1	25.7	27.0	45.4	12.9	19.2	32.2	11.4
Mar.	27.1	57.2†	18.0	24.5	42.3	14.5	13.5	33.6	8.9
Apr.	16.0	25.4	8.2	12.3	40.6	7.0	16.8	23.2	12.4
May	20.6	43.8	12.7	12.8	24.1	7.0	12.0	21.9	8.7
Jun.	11.9	19.3	4.7‡	10.0	35.3	5.3	13.0	28.4	8.5
Jul.	9.9	24.6	6.0	13.3	28.9	5.1‡	16.5	45.5	6.5‡
Aug.	23.5	35.6	8.9	29.5	46.6†	16.1	29.5	49.0†	15.9
Sept.	25.1	41.8	14.3	23.2	33.5	16.3	27.4	49.0†	18.3
Oct.	15.2	35.8	9.2	17.4	27.2	10.1			
Nov.	13.5	19.9	10.4	10.3	18.6	7.4			
Dec.	19.3	39.5	8.1	11.3	20.0	6.9			
Avg	19.9			17.7			17.9*		

* January-September only.
† High for the year.
‡ Low for the year.

TABLE 4

Yearly Average Turbidity for 5-gpm Filters

Year	Filter 10		Filter 77*	
	Turbidity—ppm			
	Avg	Max. Test	Avg	Max. Test
1949	0.01	0.50	0.05	0.58
1950	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00
1952	0.02	0.50	0.04	0.40
1953	0.00	0.00	0.00	0.10
1954	0.04	2.00	0.02	1.30
Avg	0.012		0.018	

* Results shown are composite of tests on Filters 77 and 80.

high coliform counts indicated, and another without.

The water was prechlorinated throughout the period of the test. For 1950-52, the prechlorination dosage was enough to produce substantial residual passing through the filters, and good results were expected. Beginning in May 1953, the prechlorination dosage was lowered, so that the water passing the filters had only slight residual chlorine. Postchlorination, however, was increased, so that the water on leaving the plant would have the desired residual (0.6 ppm). The filters, of course, were sampled in advance of postchlorination.

The general averages of the filters show no major discrepancy between the counts for the high-rate filters as compared with those of the filters on variable rates of 2.3-4.7 gpm, or those operated at a 2-gpm rate. The general average of the coliform bacteria (after reduction of the prechlorination dosage) has been low, and shows the water from all filters to be of high quality with respect to bacterial content. Nevertheless, enough additional chlorine was added to produce a combined chlorine residual of 0.6 ppm in the water leaving the plant. There is no reason to fear that the water from the high-rate filters is less safe than that from the 2-gpm filters. If the entire Chicago water supply were filtered at 4-5 gpm, it would be just as safe as water filtered at 2 gpm.

TABLE 5

Floc Volume for 5-gpm Filters

Year	Filter 10		Filter 77	
	Avg	Max. Day	Avg	Max. Day
1949	0.03	5.0	0.02	5.0
1950	0.00	trace	0.01	1.0
1951	0.00	0.0	0.00	0.0
1952	0.26	5.0	0.20	4.0
1953	0.07	0.2	0.08	0.3
1954	0.13	0.3	0.12	0.4
Avg	0.08		0.07	

Cotton Plug Filters

The most sensitive test yet devised for determining the amount of coagulated material passing through filter beds is the cotton plug filter. A description of this filter was published by the author in 1949[3]. The cotton is placed inside a glass tube measuring 1 in. in ID and 2 in. in length. The cotton must be packed tightly enough to prevent the development of free-flowing channels, yet not so tightly as to interfere with the flow of water. One soon learns from experience the most satisfactory amount of cotton to use and how best to pack it into the tube. Absorbent cotton is difficult to dry to constant weight. The best procedure, therefore, is to burn the cotton with the material retained by it and determine the results on the basis of the comparative weight of ash. Unless the ash content is low, the weight of the cotton ash will not substantially affect the results. At Chicago, the cotton plugs are usually changed each week. Knowing the rate of flow through the filter (usually close to 100 ml per minute), and the time in service, the content of coagulated material (expressed as parts per million of ash) may be calculated. Results of the cotton plug filter tests are given in Table 7.

The cotton plug filter is the only test that reveals any reduction in the quality of the water passed through the high-rate filters, samples of which show more ash than those from the 2-gpm filters. Though actually quite small, this increase must be taken into account in considering high-rate filtration. Use of the cotton plug filter will provide adequate warning if the coagulated material passing the filter is approaching the danger limit.

Little is known about the amount of coagulated material that passes through filter beds. That some coagulated material passes every filter bed handling coagulated water does not seem to be widely understood by filtration plant operators; or, if understood, it is considered to be of no significance. The author believes it better to record the amount of flocculated material passing through the filters, even though it is very small.

Good use of cotton plug filters was made in the Chicago Experimental

TABLE 6

Coliform Bacteria Counts

Year	Automatic Rate (2.3—4.7 gpm)	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Bacteria Count—number/100 ml			
1950	0.035	0.057	0.050	0.073
1951	0.011	0.007	0.012	0.001
1952	0.057	0.122	0.038	0.218
	0.017*	0.009*	0.011*	0.001*
1953	0.018	0.003	0.001	0.016
1954†	0.024	0.008	0.007	0.011
Avg	0.021*	0.017*	0.016*	0.022*

* Averages not including high count (caused by contaminated sample bottles) of April 1952.
† Count for 2 gpm filter for 1954 was 0.012.

Filteration Plant to compare filter efficiency. It has been 15 years since the first article describing the filter was published[4], yet so far little use has been made of this extremely sensitive device. This indicates a general lack of interest in the efficiency of filters in removing coagulated material from water so long as the filtered water is not noticeably turbid.

Cotton plug filters should be used on all of the filters in every filtration plant. They are the best means of keeping account of the efficiency of the filters. A word of caution, however: the results obtained in one plant may not be similar to those of another plant. The filters in a given plant are tested on the basis of relative efficiency. If the performance of one filter is noticeably different from that of the others, then there must be a cause. Filtration plants have been observed in which considerable flocculated material was passing through the filters. The cotton plug filter would reveal

TABLE 7

Cotton Plug Filters

Year	Avg. of All Filters	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Ash—ppm				
1949	0.047	0.045*	0.055	0.059	0.066
1950	0.037	0.028	0.048	0.045	0.060
1951	0.042	0.039	0.067	0.064	0.084
1952	0.077	0.039	0.058	0.084	0.084
1953	0.060	0.057	0.067	0.089	0.087
1954	0.058	0.056	0.073	0.090	0.082
Avg	0.054	0.044	0.059	0.072	0.077

* 3-gpm rate.

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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthrafilt and sand and saves on freight and handling charges.

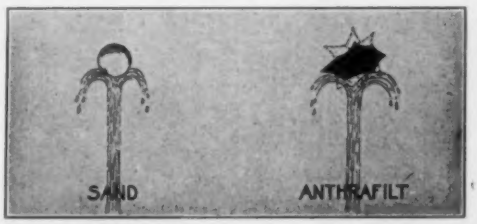
Filtration Characteristics

Anthrafilt granules are irregular shaped and of varying densities. **Weights run about 53 pounds per cubic foot as** against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. The uniformity coefficient is less than 1.75 in all sizes. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

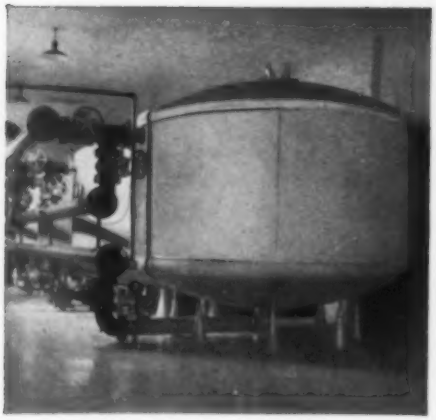
ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in Existing Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs



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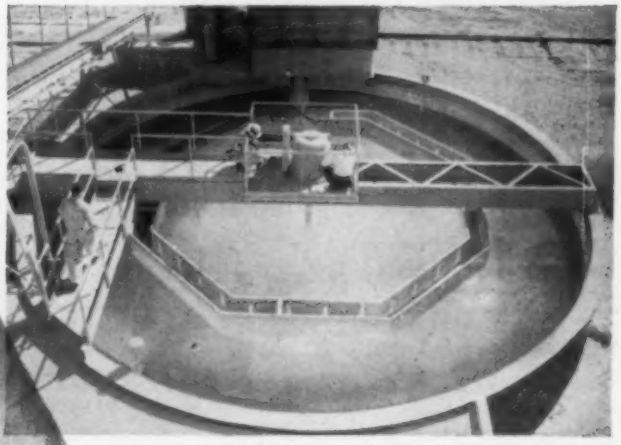

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this fact and would probably lead to remedial action. During periods of weak coagulation, a small amount of acid-treated sodium silicate is used to strengthen the coagulation at the South District plant. The use of silicate is not governed by the filtration rate, for only a few of the 80 filters operate at high rates. Rather, the need for silicate is determined by the character of the raw water. During periods of weak coagulation the coagulated material will readily pass through filter beds operated at 2 gpm, or even at lower rates of filtration.

Filter Performance

The measure of filter performance is the amount of water (in millions of gallons) passed through each filter per 1-ft increase in loss of head. The performance of the high-rate filters is compared with that of the 2-gpm filters in Table 8. Filters operated at a constant rate of 2 gpm had an average performance of 0.71 mil gal for the 6-year period, whereas filters operated at a rate of 4 gpm had an average performance of 1.02 mil gal, representing an increase in performance of 44 per cent over the 2-gpm rate. This performance has continued to increase each month throughout the 6-year period of the tests.

In the July 1950 article to which reference has previously been made[1] the seventh of a series of 20 questions frequently asked the author was: "Why is the filter performance greater for the high-rate filters than for the low-rate filters?" The answer given at that time was:

> This question cannot be answered definitely at present. In general, one would expect the filter performance to be the same regardless of rate or perhaps slightly less for the high rate. It may be, however, that the rapid flow of water into the filter causes deeper penetration of the coagulated material.

This still seems as precise an answer as may be given. One possible factor not previously mentioned is that loss of head often increases at an accelerated rate: for example, if the increase in loss of head in the first part of the filter run is 0.5 ft per hour, it may be as much as 0.6 ft or more per hour when the head loss is near 8 ft. For short filter runs (4-8 hr) the rate of clogging also increases more rapidly toward the end of the run. Starting with a higher initial loss of head on the high-rate filters, the total increase in head loss up to 8 ft is not as great as that produced by a low filtration rate. This very minor difference, however, would hardly account for the considerable increase in filter performance as the rate of filtration is increased. The assumption that the coagulated material is carried deeper into the filter bed still seems the more likely explanation.

TABLE 8

Filter Performance

Year	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Volume per 1-ft Loss of Head—mil. gal.			
1949	0.61	0.93	0.90	0.94
1950	0.76	1.12	1.16	1.27
1951	1.07	1.35	1.46	1.56
1952	0.65	1.07	1.16	1.11
1953	0.69	0.88	0.95	0.85
1954	0.50	0.78	0.81	0.85
Avg	0.71	1.02	1.07	1.10

During the first 4 years of filter operation there was a gradual decline in the number of filter washes, from 28,831 in 1948 to 23,202 in 1951. Since 1951, the number of washes has increased rapidly, with 44,382 filter washes recorded in 1954. Part of the increase in 1953, 1954, and 1955 can be attributed to the previously mentioned replacement of the raw-water meters. The chief cause has been variation in the number and kinds of microscopic organisms. In June 1954, there were 5,642 filter washes, while in August of the same year there were only 2,059. The average daily pumpage at the plant was 389 mil gal in June, compared with 361 mil gal in August. This difference in the volume of water filtered would account for only a few of the additional washes in June. The greater part of the difference was clearly caused by the variation in the number of microorganisms in the raw water—from an average of 1,130 in June to 283 in August.

A tabulation of hourly filtration rates for the 68 filters set on automatic rates has been made for eight peak days in June and July of 1954. These rates, which vary from a low of 1.2 gpm to a high of 3.5 gpm, averaged about 2.7 gpm per square foot for the days recorded. Total plant production for those days ranged from a low of 439.4 mil gal to a high of 478.4 mil gal, and averaged about 451.4 mil gal. Comparable data for 1955 show hourly peaks not exceeding those of 1954. Trail tests were made in 1955 in which the pumpage and filtration rates were raised to 640 mgd. Thus, the 68 automatic filters were operating at rates slightly in excess of 4 gpm per square foot. The objective of this test was to determine whether the plant could be operated at such a high rate. Present peak rates are only about 80 mgd below the tested maximum of 640 mgd.

Conclusions and Recommendations

If a filtration plant is designed on the basis of a rate of 3 gpm per square foot, some saving in construction cost will be made over a design based on a 2-gpm rate. The filter area will be two-thirds of that required when the customary rating of 2 gpm is used. The cost, however, will be somewhat more than 67 per cent, for the influent and effluent piping and conduit requirements will be the same as those of a 2-gpm rate. Other equipment used in conjunction with a filter (such as operating tables) also will be the same. The cost of the filters alone may be lessened as much as 25-30 per cent as a result of using the 3-gpm rate.

The saving in operation cost will be very little if any; however, the cost certainly should not be greater. The fact that there is greater filter performance indicates slightly fewer filter washes, but this does not necessarily imply a saving in operational cost: certain equipment such as backwash valves, is adversely affected by too little use.

On Jan. 18, 1952, the entire South District plant was placed on a high-rate test by reducing the number of filters in operation. Operation of the plant was continued in this manner until Feb. 1, 1953. Of the 80 filters, 30 were cut off, alternating from one filter to another, so that no single filter would be out of service for more than a week at a time. During the summer months, when the load was high, it was necessary to turn on a few of the idle filters for short periods during the peak demand. When the demand rate for the operating filters increased to 4 gpm, the filters were watched closely so that a few of the idle filters could be cut back into service to maintain the load at no more than 4 gpm. As soon as the peak load was over in the evening, the number of filters in service was reduced to 50. The high-rate filters used in the previous tests were kept in service at the same fixed rates—that is, 4, 4.5, and 5 gpm.

The author wishes to make quite clear that he does not advocate indiscriminate use of the 3-gpm rate. Experience with such a rate, however, in plants throughout the country, indicates it may be used in many circumstances. The water should be well conditioned, and increased rates of filtration should not be accompanied by

a reduction in mixing and settling times. Generally, this means that plants designed on the basis of 2 gpm should not be converted to the 3-gpm rate unless operation demonstrates that shorter periods of mixing and settling produce good conditioned water for the higher rate. This statement applies mainly to the gradual accommodation of plants now in operation to meet increased water use. In the design of most filtration plants provision is made for overloads of 25-50 per cent. A design based on the 3-gpm rate should be capable of handling such an overload.

The author cannot too strongly insist on the importance of making liberal allowances in designs for overloads on the filters. If the designer chooses to call the rating 2 gpm, and designs on that basis, then he should provide for an overload of at least 100 per cent. The mixing and settling basins also should be designed with considerable excess capacity. As the load on the plant increases, the operator can tell when an extension is needed. It may be when the peak consumption produces a filtration rate of 2.5, 3, 3.5, or 4 gpm. The opinion, expressed by many, that filtration rates must be maintained at or near 2 gpm without exception is in contradiction to experience, and a deterrent to progress.

Summary

1. Water such as that of the Great Lakes may be filtered at rates of 5 gpm per square foot of filter surface without depreciation of quality, especially with reference to bacterial content.

2. Filters operated at a rate of 4 gpm may be maintained in service 97.9 per cent of the time, provided the filters are washed and returned to service with reasonable speed.

3. The length of filter run is almost inversely proportional to the filtration rate: that is, filters operated at 4 gpm will permit runs approximately one-half the length of those possible at a 2-gpm rate.

4. The turbidity of water filtered at rates of 4-5 gpm is not measurably greater than that of water filtered at a 2-gpm rate.

5. The floc turbidity, measured as floc volume, it not greater for the high-rate filters than for the low-rate filters, except at infrequent intervals of short duration. The evidence of decreased efficiency at such times is not strong.

6. The bacteria-removal efficiency of filters operated at 5 gpm is equal to that of filters operated at 2 gpm. Good reduction of coliform bacteria was observed for the high-rate filters even when there was very little residual chlorine in the filtered water and before postchlorination.

7. The amount of coagulated material passing through a filter bed is best measured by the cotton plug filter. Although a slight increase of coagulated material does pass through the high-rate filters, the amount is so small as to be of minor significance. The cotton plug filter is the only device revealing this difference, and should be installed on all filters in every filtration plant.

8. The filter performance (volume of water filtered per 1-ft increase in loss of head) is greater for the high-rate filters than for the 2-gpm filters.

9. The 80 filters of the South District Filteration Plant had 44,382 filter washes during 1954. Peak demand for water is now within 80 mgd of the 640-mgd maximum capacity of the plant, which was run on a high-rate test for a period of 1 year.

10. High-rate filters should be introduced only when there is evidence that such rates will not decrease plant efficiency.

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Diatomaceous Earth Filtration

by HENRY N. ARMBRUST

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IN VIEW OF PRESENT developments and future expectations, use of the term "diatomaceous earth filtration" is somewhat restrictive. It is more realistic to speak of "filter-aid filtration" and "filter-aid filters." Although diatomaceous earth is by far the most common filter-aid material in use today, there are several other materials used in this type of filtration. These include: Wollastonite, expanded perlite, granular cellulose materials, asbestos fibre, activated carbon and other finely divided substances.

Essentially, a filter-aid filter consists of a layer of finely divided particles deposited upon a porous supporting membrane, which serves as an underdrain. The size of the particle is such that the pores, or openings between them, are ultra-microscopic. When water is passed through the layer, suspended matter is caught on the surface and thus removed from the water or other liquid.

Filter-aid filtration developed from the use of unglazed porcelain and other similar materials as filtering media for a very high degree of turbidity removal. The unglazed porcelain filter is very efficient in the removal of microscopic particles, including bacteria, but filter runs are short, rates are extremely low and cleaning the filter is difficult. The use of an easily removable mat of finely divided particles as a filter medium was an advance in the art which took this type of filter out of the laboratory and put it into common use.

History

Filter-aid filters were used for many years prior to 1940 for the filtration of beer, wines, oils and chemicals. It was not until World War II, however, that the filter-aid filter for the continuous purification of drinking water became a practical reality. The next step was the application of these filters to domestic use.

At the beginning of the war, American troops and the land forces of the Navy were supplied with small, portable, sand-filter plants, which provided flocculation, coagulation and sterilization. Under field conditions, this type of purification plant was not efficient in removing amoebic dysentery cysts and blood flukes. Meanwhile, the British were using a diatomaceous earth filter in their portable water-purification plants and this type of filter was found to be capable of turning out acceptable water.

At the suggestion of the National Research Council, the U. S. Army undertook the development of a portable, diatomaceous earth, water-purification unit at Fort Belvoir, Va. Subsequently, the U. S. Navy contracted with Proportioneers, Inc. for the development of a portable, diatomaceous earth, filter plant for use by the Navy Civil Engineers Corps. These developments proceeded independently of each other. At the end of the War the U. S. Navy had some 1,500 units, many of them in use at advanced bases in Okinawa and other locations, and the U. S. Army also had a number of units.

Design Features

Both of these military units used cylindrical, or tubular, filter elements; both used a precoat or initial filter mat, plus a continuous feed of diatomaceous earth, termed "body feed," into the incoming water. (Body feed is used to prolong filter runs by maintaining an open porous cake.) Here the similarity ceased.

The Army unit was operated at a constant input pressure. Thus, with a clean, new precoat the filtering rate might run up to 10 gal per minute, but as the pressure loss increased, the rate fell off until it reached a point below that required. The filter-aid was fed by a constant dilution device. Army Engineers believed that the decrease in filtering rate caused by the clogging of the filter cake (and consequent increase in pressure loss) followed the dilution curve; thus it was believed that the rate of body feed would be in proportion to the rate of flow of water through the filter.

Backwashing was accomplished by setting a four-way valve so that the inlet to the filter (connected with the pressure side of the supply pump during the filtration part of the cycle) was connected to the suction side of the pump and the filter was backwashed by suction. The Army filter elements were patterned after the British Stellar element, consisting of Monel metal or stainless steel, round wire, wound on a perforated plastic core.

The Navy unit consisted of a machinery section which was a frame, holding: (1) water pump; (2) duplex-positive-displacement-pump-type feeder for hypochlorite and filter-aid slurry; (3) pump engine with belt drive to pump; (4) hypochlorite reservior, and (5) baffled tank with an agitator, driven through a flexible cable from a shaft of the feeder. The filter, separate from the machinery section, contained porous aluminum-oxide tubes as septa and was equipped with a rate-of-flow indicator, graduated in gallons per minute.

This purification unit was operated at a constant rate and diatomaceous earth body feed was fed in a predetermined direct proportion to the rate of flow. Pressure backwashing was accomplished by a separate pump, using filtered water taken from a storage tank. The use of this purification unit enabled the Navy Civil Engineer Corps to take water from such polluted sources as rice paddies and to deliver a safe, potable product to their personnel.

Subsequent to the presentation of papers on these units at the Engineers' Society of Western Pennsylvania in the mid-40's, several manufacturers became interested in diatomaceous earth filters. The result was that several types of equipment were offered as "cure-alls" for many water-filtration problems. Lacking proper background and experience in the field, the efforts of some of these manufacturers resulted in failure of equipment to perform properly. Some of these firms have since discontinued manufacturing these units, but the damage caused by lack of experience and misapplication of the equipment delayed the proper development and use of filter-aid filters.

Principles of Operation

Now let us consider how the fil-

*Reprinted from Jour. NEWWA, Vol. 69 No. 3, p. 287 (1955)

ter-aid filter resembles a sand filter. The sand filter, either the rapid sand or the slow sand type, consists of an underdrain system of collecting pipes with superimposed layers of coarse stone, coarse gravel, fine gravel, coarse sand and, finally, fine sand at the top. In the rapid sand filter, these layers exist in either an open tank (gravity filter) or a closed tank (pressure filter). Slow sand filters are of the open or gravity type. Direction of flow in both types is downward through the filtering medium. A sand filter is not a completely effective filtering unit until a gelatinous filtering mat has been deposited on and in the top layer of sand. In the rapid sand filter the mat is chemically precipitated floc. The filtering mat in the slow sand filter is a "schmutzdecke" of gelatinous material, which is removed from the water as the filter is operated to waste.

In the filter-aid filter, the cylindrical shell is divided into two compartments by a separator plate, or tube sheet, containing a number of holes. The elements or septa are porous cylindrical tubes, closed at one end, open at the other. The open end of these tubes is inserted into the holes in the separator plate. Clamps, tie rods and bottom caps hold the cylindrical tubes tightly against the holes in the separator plate. Flow direction is opposite to that of a sand filter. Water enters the bottom or raw-water compartment, passes through the filtering tubes, and up into the filtered-water compartment. On these tubes is deposited a filtering mat or "precoat" layer of diatomaceous earth, approximately one-tenth of an inch thick. This precoat of filter-aid is held on the surface of the tubes by the flow of water and slight pressure differential between the two compartments.

The section of the filtering mat is similar to the schmutzdecke of slow sand filters. Inasmuch as the particles of filter-aid are microscopic, the openings through the mat are devious and are ultra-microscopic; therefore, foreign matter is effectively entrapped on the surface of the filtering mat. As flow continues, more and more suspended and colloidal matter is caught on the filtering mat (see Fig. 1). If flow were allowed to continue under these conditions, the mat would become clogged, the rate of flow would decrease to a low value and the pressure loss would increase, thus making operation uneconomical.

To avoid this clogging action, a constant addition of filter-aid is made in the proper proportion to the rate of flow. This is known as "body-feed". Body feed extends the length of filter runs up to 1,000% or more, by continually building up the cake, separating the particles of foreign matter and preventing the total clogging of the openings. The dosage of body feed is critical up to an optimum proportion, in that a slight reduction of the dosage will result in a marked decrease in length of filter run. Above the optimum body-feed rate, however, a relatively large increase in dosage will produce only a slight reduction in length of filter run.

Backwashing

In the case of the rapid sand filter, backwashing is accomplished by reversing the flow through the filter, at a rate approximately three to five times the normal filtration rate. In this manner, the sand bed is expanded, the grains are separated by the velocity of the water and agitated until they have scrubbed themselves free of the filtering mat material, which is carried out to waste. Backwashing normally requires about an hour's production of water by the filter. Slow sand filters are usually drained and the top inch or so of sand and accumulated schmutzdecke is removed with rakes and shovels. In each case, before resuming filtration, a new mat is built up as the filter is operated to waste.

Most filter-aid filters have an air chamber in the filtered water section, where air is entrapped. At the end of a filter run, which is determined by a decreased rate of flow or an arbitrary limit of pressure loss, the effluent line is closed. Closing this line causes the pressure in the filtered-water section to build up to the cut-off head of the pump (if one is used), thus compressing the air. If the flow is by gravity the pressure is built up to the maximum static influent pressure. Next, the influent valve is closed and a quick-opening backwash drain valve is opened. The pressure in the raw-water section immediately decreases toward zero and causes an explosive expansion of the air trapped in the top of the filter. This sudden expansion of air drives the water in the upper section back through the filter elements. This reverse flow, momentarily at rates of several hundred gallons per minute per square foot, literally blasts the accumulated filter cake loose.

An air vent is then opened and the filter is drained and rinsed. A new precoat is applied and the filter returned to service. Backwashing in this manner requires approximately two to three times the volume of water contained in the filter shell, a volume equivalent to only a few minutes' filtered-water production.

Types of Filters

There are several types of filter-aid filters, practically all of which have rigid septa, on which an initial filtering mat or precoat is formed. Perhaps the oldest and most widely used in industry are the plate-and-frame filter and the leaf filter, which must be dismantled and cleaned manually after every filter run. The majority of filters used in municipal water works and swimming pools are pressure filters of the tublar-element type. In the filter-aid filter, a 30-inch-diameter shell can contain as many as fifty-five 2½-inch-diameter elements more than 4 feet long, making a total area of approximately 156 sq ft of

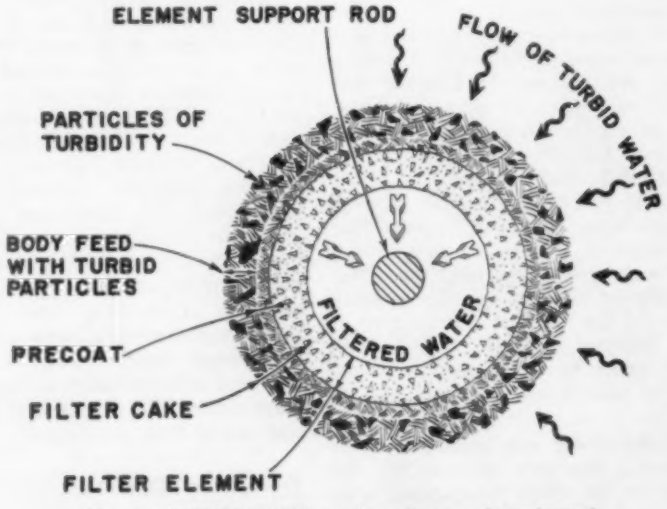


Fig. 1—DIAGRAM of filter cake and precoat on element

filter surface. Contrast this with approximately 5 sq ft of area of a sand bed in a 30-inch shell.

Besides the pressure filter with tubular elements, the plate-and-frame filter, and the pressure leaf filter, there is a vacuum filter with tubular elements, as well as a vacuum-drum filter. The former consists of an open tank, containing an underdrain system and a multiplicity of tubular elements, extending upward. This filter is the nearest approach to a conventional rapid sand filter. A pump takes suction from the underdrain manifold and consequently the maximum differential head across the elements is approximately 25 ft of water. The drum-type filter is essentially the same as the vacuum sewage filter, except that the drum is precoated with approximately two inches of filter-aid. As it revolves, a knife removes the filter cake and one or two thousandths of an inch of the initial precoat, thus continuously exposing a new surface to the liquid being filtered.

Filter Elements

Several different types of filter elements are available. These include wire or plastic cloth; round wire, wound in grooves on a central perforated core, trapezoidal, self-spacing, stainless steel ribbon, wound on edge on a perforated metal core; porous, sintered aluminum oxide (Fig. 2); heavy trapezoidal wire, wound and spot-welded to a perforated metal core (Fig. 3); and porous, elastic plastic or rubber on a heavy wire-mesh core. Each of these elements has its advantages and disadvantages.

The ideal element is one which is chemically inert and, therefore, resistant to corrosion. It must be rigid, to prevent cracking of the filter cake through movement of the supporting septum, as the pressure differential varies across the element. It should backwash easily and cleanly, with even distribution of the backwash flow, and it should be capable of being chemically cleaned without removal from the shell. Above all, it must take an even precoat, which means that it must be homogeneous as to permeability, and it must be relatively inexpensive.

The wire and the porous stone elements are the most widely used in present-day filter-aid filters. While the wire-wound element is easier to clean mechanically, it is expensive and chemical cleaning can cause disintegration. The porous stone element is harder to clean mechanically, but is readily cleaned chemically. It is, however, more fragile. In recent years, aluminum oxide is the only material which has been used for porous stone elements. Some published articles, in the past, have referred to "carborundum elements", but this is a misnomer through association with the name of one of the manufacturers of aluminum-oxide tubes. Carborundum is actually silicon carbide, which has not been employed as a standard-production filter-element material.

Filtering Rates

Filtration rates with filter-aid filters are gradually being standardized at not more than one gpm per sq ft for industrial or municipal applications, and not more than 3 gpm per sq ft for swimming-pool applications. There is a growing tendency to limit permissible swimming-pool filtration rates to an even lower figure. Generally speaking, filtration at rates up to 10 gpm per sq ft will produce water of satisfactory quality and there are some manufacturers who recommend their filters for operation at rates well above those mentioned. The lower rates assure much longer runs and a greater degree of freedom from trouble.

Operation

The filter-aid filter is unsurpassed for the removal of turbidity, producing a water with only 0.1 to 0.2 ppm of turbidity, or less, even when filtering turbidities as high as 100 ppm. It is efficient in the removal of algae. It is not recommended for a high degree of color removal, where the color is true color due to tannic and humic acids. With the proper filter aid, effective removal of bacteria by a filter-aid filter is similar to the removal of bacteria with slow sand filter.

Although the filter-aid filter is not recommended for true color removal in water supplies, when used in swimming pools where the water is recirculated, color removal is normally satisfactory.

In swimming-pool filtration, it is recommended that chlorine be applied after the water has passed through the filter, particularly in cases where the make-up water contains iron or manganese. In these cases, it is desirable to add make-up water over the edge of the pool, or through a make-up tank leading directly into the pool, rather than into the suction of the pump. It is desirable, also, to maintain the hardness of the water and the pH at a level which will prevent corrosion of piping and consequent dissolving of iron, which will later precipitate in the filter elements. Where iron-bearing waters are brought directly into a pool and proper conditions are maintained, the iron will precipitate and agglomerate in the pool, thus forming particles large enough to be caught on the filter cake, rather than penetrating it and plating out on the elements. Filter shells and steel parts should be adequately coated to prevent corrosion.

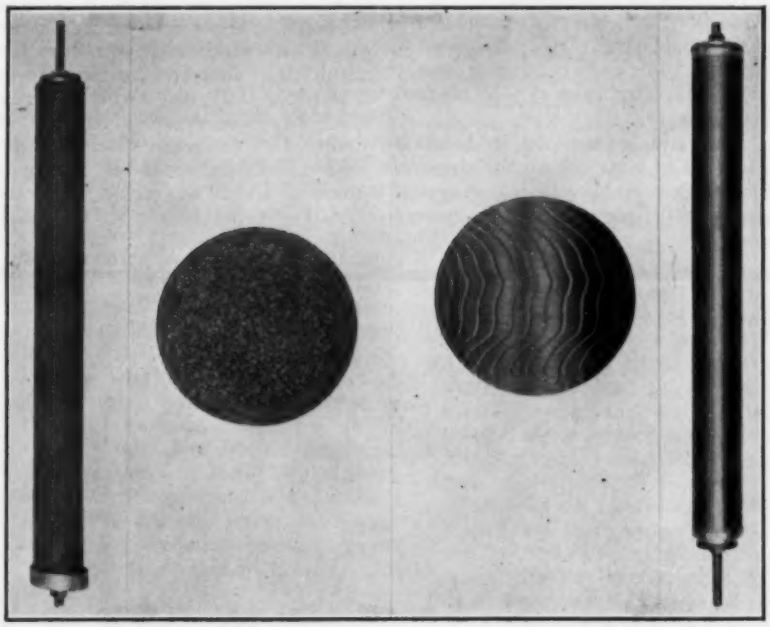


Fig. 2—POROUS aluminum-oxide-type element

Fig. 3—TRAPEZOIDAL stainless-steel-ribbon-type element

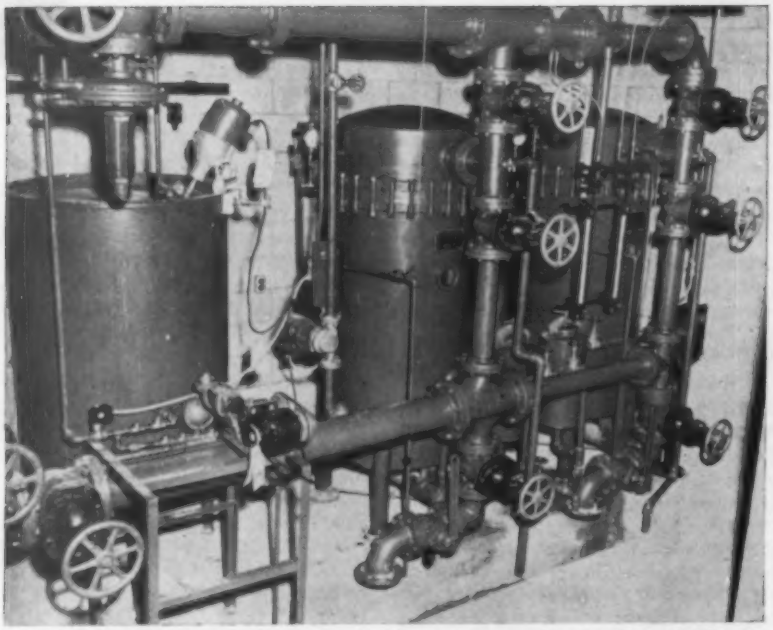


Fig. 4—INSTALLATION of diatomite filters at Bangor-Monitor Twp., Mich.

Problems

Troubles in the field have been mainly of two types: misapplication and difficulties of a chemical nature. Misapplication has resulted from improper engineering, caused by lack of understanding of the capabilities of filter-aid filters, or by the desire of a manufacturer to employ excessive filtering rates by reducing filter area to lower sales prices.

Troubles of a chemical nature include floc carry-over, iron and manganese, and electrolytic corrosion. If coagulant floc is carried over to the filter, the filter cake can be blocked very quickly.

Iron and manganese in solution will tend to plate out on the element, blocking it and requiring chemical cleaning. Where iron and manganese are present, preventive maintenance programs have been instituted, in which the filters are periodically chemically cleaned by means of muriatic or oxalic acid for iron removal, and acid and sodium acid sulfite for manganese.

Metal filter elements and other parts are corroded by electrolysis, due to the use of dissimilar metals. In some cases, slimy impurities present in excessive amounts can cause rapid blocking and consequent short runs. Sometimes, short runs of only a few hours are encountered with very low turbidities, where the turbidity is of a slimy or flocculant nature, whereas there have been cases of runs of 18 hours' duration while filtering water with turbidities of about 100 ppm, much of which was algae. Thus the turbidity value is not an indication of the length of run which might be expected, as the reading does not take into consideration particle size, color, shape or character.

What of the Future?

Filter-aid filters are at present used in many industrial water-supply installations and also in an increasing number of municipal installations, ranging from water plants with a capacity of a few thousand gallons per day up to 2 mgd. Representative municipal installations include Cherry Valley, N. Y., Willsboro, N. Y. Sherburne, N. Y., Gasport, N. Y., Tupper Lake, N. Y., Bangor-Monitor Township, Mich. (Fig. 4), Mounds, Ill., and others.

To those who contemplate the possibility of using filter-aid filters in municipalities, it is recommended that thorough studies of the water be made by a competent engineer and that a pilot plant be operated during those periods of the year when the turbidity of the water is highest, as well as in the algae season. The water should be chemically conditioned to reduce the possibility of corrosion or precipitation of scale.

The development and employment of the filter-aid filter for municipal water-supply filtration is the first major step forward in the filtration picture in many years. Research is being carried on with various types of filter construction and with various types of septa. Work is also being done on the problem of establishing a measure of filterability. Filter-aid manufacturers are busily engaged in the testing of new materials. The next ten years will bring the development of new filter aids and techniques, which will enable the filter-aid filter to be used in even the largest water plants with a very great saving in construction and operation costs.

Taste and Odor Control

TASTES and odors in water supplies are caused by either algae, decaying leaves and vegetation or by sewage and industrial wastes. Algal tastes are most prevalent and annoying.

Odors are determined by the "Threshold Odor Test" in which the odor is evaluated by smelling samples of water diluted with various amounts of odor-free distalled water. The Threshold Odor Number equals the volume of odor free dilution water divided by the volume of odorous water in that dilution above which the odor cannot be detected. A hot threshold number of more than two can usually be noticed by consumers.

Tastes and odors caused by algae can be controlled in two ways: (1) Preventive treatment by the use of copper sulfate added to kill off the algae before their concentration becomes great enough to cause severe odors and tastes. (2) Corrective treatment to remove or destroy odors already formed. The latter treatment includes aeration, chemical oxidation with chlorine dioxide, ozone or chlorine, and adsorption by activated carbon.

Chemical Treatment

In chlorine dioxide treatment, sodium chlorite solution is treated with a chlorine solution to produce chlorine dioxide (ClO_2), a strong oxidizing agent, soluble in water. A proportioning chemical feeder is used for the sodium chlorite solution and a chlorine gas feeder for adding the chlorine. A special generating column is used to mix the two solutions and produce the chlorine dioxide. The mixture from the generator is discharged into the water to be treated. It is the practice to add chlorine in a ratio of 1 part chlorine to 2 parts sodium chlorite in order to assure enough chlorine to lower the pH to 3.5 at which value chlorine dioxide is produced. Chlorine dioxide may also be generated by adding sulfuric acid to sodium hypochlorite and adding this mixture to a sodium chlorite solution.

Ozone for taste and odor control is generated in a special apparatus called an ozonator. Air, from which all moisture is removed, is passed through the tubes of the ozonator and subjected to a high voltage brush type electrical discharge. Approximately one per cent of ozone is produced. The ozonized air is discharged into the water under treatment, through a diffuser system. The ozone oxidizes the taste and odor compounds. Some difficulties may be experienced with this treatment as ozonation sometimes fixes certain tastes and odors and actually prevents their removal from the water.

The treatment of water with chlorine for the removal of tastes and odors is discussed in Section V.

Activated Carbon Treatment

By far the most popular corrective treatment is adsorption using activated carbon as the adsorbent. Activated carbon is a finely divided carbon with a highly adsorbent surface which will attract and hold these taste and odor compounds. Powdered activated carbon is most popular although granular carbon is used in beds in small installations.

Extremely small particles give a greater degree of surface exposure and the porous structure of activated carbon adds to this surface. It has been calculated that a single cubic inch of activated carbon has a total adsorption surface of 10,000 square yards. The fineness of the particles makes it possible to disperse the activated carbon throughout the water and for it to remain suspended for some appreciable period of time.

The adsorptive capacity of activated carbon is rated by its ability to adsorb pure phenol. The phenol value of a carbon is that amount of activated carbon in parts per million necessary to reduce phenol concentrations from 0.1 ppm to 0.01 ppm. Carbons with a phenol value greater than 30 are seldom acceptable for water treatment.

Powdered activated carbon is very finely divided and tends to be dusty when handled. To prevent dust it is fed from specially adapted chemical feeders, or it is mixed with water and fed as a slurry.

The most popular point of application is prior to coagulation although it may be added after coagulation. It is always added prior to filtration. When added ahead of coagulation higher doses are possible without adversely affecting filter runs, and at that point it will stabilize sludge in the settling basins.

Some operators like to add activated carbon just ahead of the filters but the dosage must not be high enough to decrease filter runs appreciably, and care must be used to prevent carbon passing through the filters.

The use of other chemicals also influences the point of carbon application and the amount of carbon required. If pH adjustment is practiced, the carbon should be added 15 to 20 minutes before the addition of lime or soda ash. Activated carbon should never be added with chlorine at the same point as the carbon will adsorb some of the chlorine and reduce its disinfecting power. These chemicals should be added at least 15 minutes apart in the treatment works. Which one should be added first depends on the local situation and condition of water being treated, but generally the carbon should be added first since it will remove odors which may be emphasized by chlorination.

The amount of carbon to use is determined by laboratory tests using odor free water and may run from 20 to 40 lb per mil gal. Where laboratory facilities are not available, carbon dosage determined by the "hit or miss" method, may be either over or under that actually required. The best method of determining the amount of carbon to add is to utilize the Threshold Odor Test. Samples of raw water are treated with increasing amounts of activated carbon in a technique similar to the coagulation jar test. Each sample is also treated with other chemicals which are used in the plant, in the same order and same time sequence as used in the plant. The threshold odor number is determined on each sample after treatment. The amount of carbon used to produce the desired threshold odor number in the samples, is used as a guide to the proper dosage of activated carbon in the plant.

Since activated carbon accomplishes better results in plant practice than on small scale laboratory tests, it is necessary to develop a relation between laboratory results and plant scale dosage. Sometimes as little as one half or one third of the laboratory indicated dosage is actually needed in plant operation.

Activated carbon has also been used effectively to control algae growths in small reservoirs and sedimentation tanks. Using the blackout technique activated carbon is added in sufficient quantity to prevent the penetration of sunlight into the water. Without sunlight, algae growth is minimized. This treatment is used only on sunny days.

Studies at St. Louis County Water Co. indicate that approximately one fourth pound of activated carbon will blackout 1000 sq. ft. Carbon added in this manner reduces the amount required for taste and odor removing the treatment plant.

Algae Control With Copper Sulfate

by W. D. MONIE

Chief Engineer, The Portland Water District, Portland, Me.

ALGAE GROWTHS are one of the principal causes of taste and odor in a water supply. Thus the control of algae growth is important if the customers of a water company are to receive a product of the highest quality.

Other than the objectional features of taste and odor is also the possibility of the effect upon humans of toxic products given off by the disintegration of algae, especially the blue greens. Fitch et al[1] show that cattle and sheep have been killed in numbers within a few hours after drinking water heavily loaded with Anabaena. A study to determine possible effects of disintegation of large numbers of algae in connection with gastro-intestinal outbreaks in late summer would be well worthwhile.

Algae control to be successful must be a preventive measure and not a cure. The removal of algae by treatment at the proper time from the standpoint of economy and before the algae cause objectionable taste or odor is the true science of algae control.

Every problem, regardless of its complexities, is solved by a common sense application of fundamentals. The problem of algae control is no exception, and it is with the common sense application of fundamentals pertaining to this problem that this paper is concerned.

A, B, C, of Algae Control

The three factors most important in algae control with copper sulphate are:

A. The ability to determine when it is necessary to treat a supply.

B. The ability to determine the correct amount of copper sulphate to apply when treating.

C. The ability to apply the treatment so that uniform distribution of the copper sulphate is obtained.

Microscopic Examination

The first step in analysis is the identification of and count of the algae present in a water supply. This step is accomplished through microscopic examination.

For the operator who has not had training in microscopic indentifica-

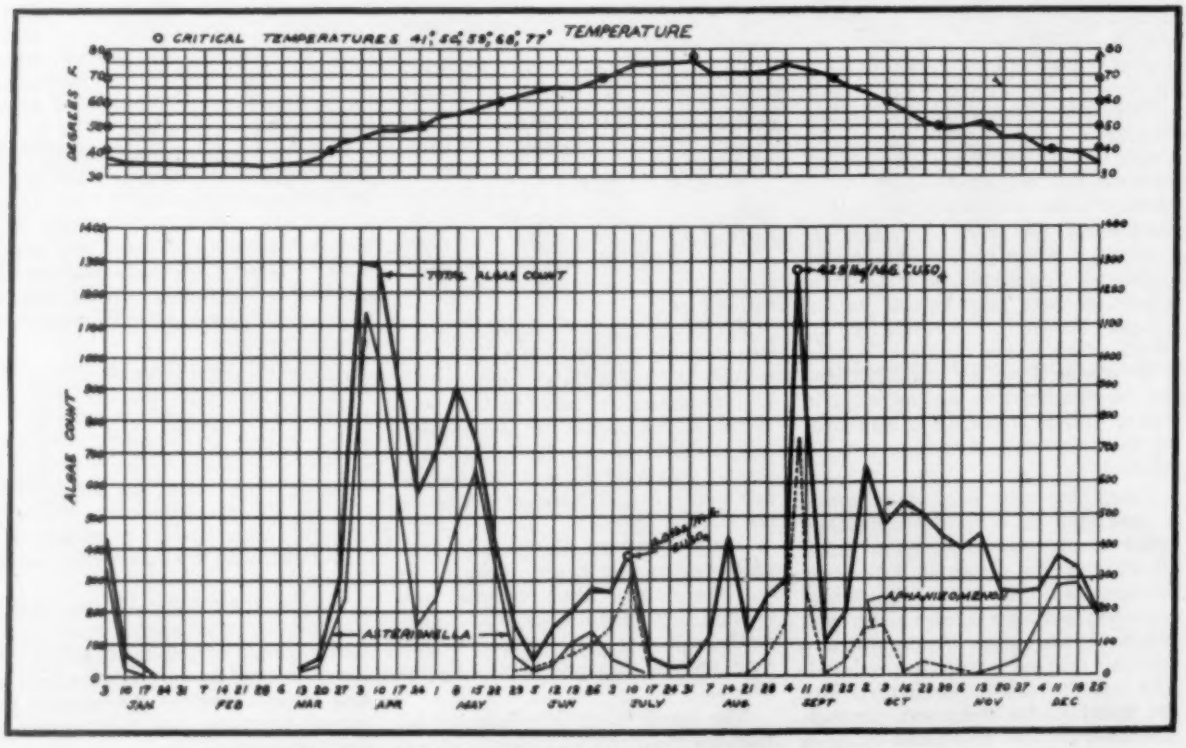


Fig. 1—GRAPH of year's study of algae growths in reservoir

tion of algae there are many aids. Illustrations of the more common troublesome algae can be found in the 10th Edition of Standard Methods for the Examination of Water, Sewage, and Industrial Waste[2]; Whipple et al[3]; and Algae of Importance in Water Supplies[4].

The most common method of microscopic laboratory analysis is accomplished by the Sedgwick-Rafter method. Laboratory equipment necessary for microscopic examination:

1—microscope
1—Sedgwick-Rafter cell
1—Sedgwick-Rafter cell funnel
1—pound Berkshire sand
12—filter discs
1—500 ml graduated cylinder
1—10 ml transfer pipette
1—1 ml 1/10 Mohrs pipette

In preparing samples for examination by this method, reservoir water is filtered through Berkshire sand, and the sand washed with distilled water. A 1-ml portion of this concentrate is then placed in a rectangular Sedgwick-Rafter cell and examined under a microscope having a magnification of 100X. If an ocular micrometer is furnished, 10 standard units are counted and the total number of organisms in the 10 units comprise the algae count. Without an ocular micrometer, 10 separate fields are counted and totaled. The algae count without the micrometer is about 15 per cent higher than a count in standard units.

For comparison purposes the amount of reservoir sample (usually 500 ml), and the amount of distilled water, (usually 10 ml) used for the concentrate should always be the same for each analysis. If it is desired to convert results to standard units or total count, proceed as outlined, starting on page 455 of "Standard Methods"[2].

Details of the method of concentrating samples by the Sedgwick-Rafter Method are given on page 442 of "Standard Methods"[2].

In making microscopic examination always remember that samples must be collected from the reservoir. If samples are collected from a main or after passage through a pump, delicate organisms are broken up and some become unrecognizable. It must be emphasized that samples for microscopic examination drawn from the mains *are of little value*. For bacteriological examinations such samples are satisfactory, but for organisms larger than bacteria, such samples give a wholly inadequate picture of what is going on in the reservoir.

It is advantageous to obtain samples periodically from different sections of the reservoir. Depth of water, exposure to sunlight, and other factors will cause surprising differences in type and number of algae present in the various sections of the reservoir. An objectional algae may start growth in a shallow area and be the seeding point for the entire supply when conditions for growth become favorable.

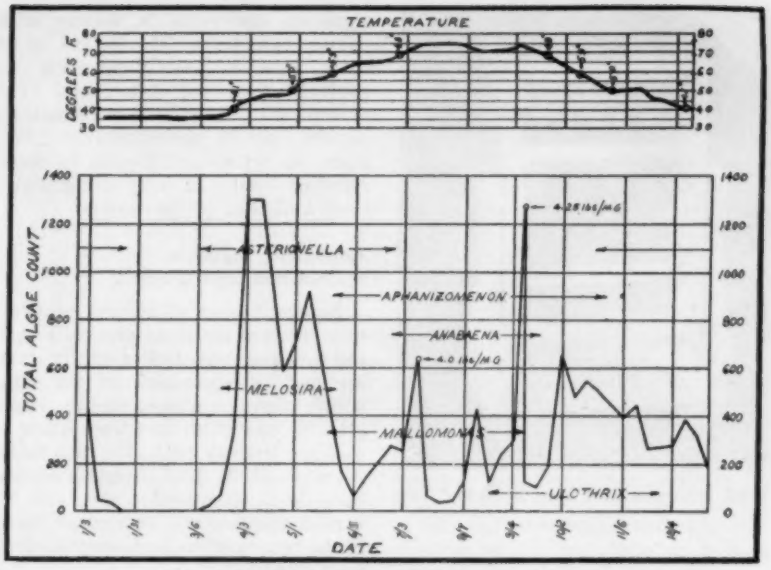


Fig. 2—RECORD of algae growths, types and counts
Reservoir temperature shown in top graph

Importance of Temperature

An important supplement to microscopic examination is a thermometer. The growth of different types of organisms can be anticipated by the temperature of the water, especially surface temperature.

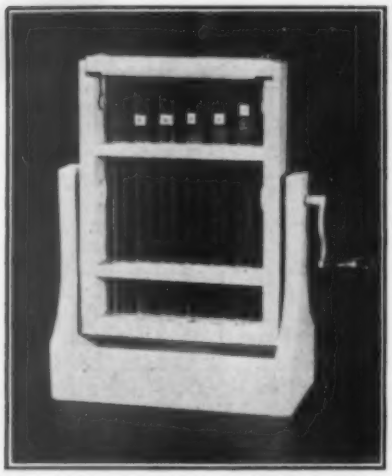
In the discussion of a paper on algae control in 1941, Dr. Thurlow P. Nelson[5] stated that Dr. Setchell, Botanist of the University of California, pointed out that there are definite ranges of temperature within which various flowering plants begin to grow and higher ranges at which they will flower. These critical temperatures were found to lie close to 41°, 50°, 59°, 68°, and 77° F. His studies showed that as the temperature passed the critical point certain species were suddenly stimulated to activity. Hydro-biologists working with algae and protozoa are finding similar critical temperatures. Owing to the more gradual temperature changes which occur in water, these ranges are more easily recognized and delimited than is the case with land plants.

Yearly Graph Shows Temperature Effect

Figure 1 is a chart showing total algae count by weekly average for a typical year. The temperature of the water throughout the year is shown at the top of the figure. Laboratory analysis is accomplished by the Sedgwick-Rafter Method. The curve marked "Total Algae Count" in this figure is the weekly average of the daily algae counts. The finer curve marked "Asterionella" is the weekly average of the count of Asterionella only. Likewise the dotted curve is the weekly average of the Aphanizomenon count only. The circles in the total algae curve indicate the points of treatment with copper sulphate. The circles on the temperature curve show the critical temperature points.

In reviewing Fig. No. 1 we note that there is a marked decrease in algae as the temperature drops below the first critical point of 41°. In fact, when the temperature of the water dropped to about 35°, to all practical purposes there were no algae present. Then in March a large increase in organisms was noted as the temperature passed the critical point of 41°. Then a drop in algae occurred as the temperature neared the second critical point of 50°, followed by a marked increase immediately after passing the 50° point around April 24th. High counts at this time were largely due to Asterionella, which could be tolerated, so no treatment was made.

Next there was a decrease until the water temperature began to approach the fourth critical point of 68°, followed by a marked increase in algae growth as the temperature neared the fifth point of 77° F. This increase was due principally to Aphanizomenon, which can cause trouble, and therefore was promptly squelched on June 8 by a copper sulfate treatment



TUBE inversion rack used in "D.M." Test
Honesdale, Pa. Water Co.

of 4 lb per mil gal.

The next marked increase of algae occurred as the temperature again approached the critical point of 77° at the end of August and the beginning of September. Again this increase was met with a copper sulfate treatment of 4.25 lb per mil gal. After September small increases in algae counts are noted around the critical points of 59°, 50°, and 41° with a sharp drop as the water cools below 41°.

Asterionella and Aphanizomenon

Examining the curve of Asterionella, it is observed that there is a major peak occurring after passing the critical point of 41°, a smaller peak after passing 50°. There is also a slight increase around June 26th, but note how the temperature curve flattens out at this point, caused evidently by cool nights. Asterionella passed out of the picture after the temperature passed the critical point of 68° but note how Asterionella again appears in November around the second critical temperautre point of 50°, with a marked increase at 41°, and then a drop as the temperature decreased to approximately 35°.

As the curve for Aphanizomenon shows, it appeared in June as the temperature passed the critical point of 59° with a marked increase after passing 68°. Note how the treatment which was made for Alphanizomenon knocked it out of the picture until August 14th and then note the rapid increase as the temperature approached the critical point of 77° to be squelched again by copper sulphate. Aphanizomenon then petered out as the water cooled, disappearing near the temperature point of 50°.

The author does not wish to create the impression that some types of algae do not grow in waters with temperature below 35° to 34° or at these temperatures. Organisms do grow in this cold water, and even underneath the ice. One in particular, Synura, can be obnoxiously troublesome, as its presence even in small numbers causes a very disagreeable taste and odor in the water.

Anabaena, Melosira, Mallomonas and Ulothrix

Figure 2 is an algae and temperature curve of the same year as Fig. 1. On this graph are indicated the starting and ending points of six algae which were prominent in the year's growth. No effort has been made to indicate separate peaks for each algae. Asterionella and Aphanizomenon have been discussed above and no further mention will be made of them. Some comment on four other algae is warranted.

Anabaena growth occurred after the water temperature passed the critical point of 68° and how it disappeared after the water again cooled below 68°. The second treatment with copper sulphate undoubtedly stopped it from dragging on.

Melosira started growing as the temperature reached the first critical point of 41° and ended growth at a temperature just above 59°.

Mallomonas began growth about 59° and disappeared as the temperature came back down to near 59°, immediately after the second reservoir treatment.

Ulothrix began growth near 70°, after the first treatment had removed Aphanizomenon, and remained until the temperature approached 41°.

It is well to remember that temperature changes can be rapid in shallow areas of a reservoir or lake. These temperature changes may stimulate algae into activity and cause the appearance of unexpected algae, though usually not in large numbers.

Therefore, with an eye on the water temperature, an operator can anticipate periods of rapid algae growth and the type of algae to expect. Also he will be able to tell when it is necessary to pay particular attention to microscopic examination.

When and How to Treat

It is the practice of some operators to treat a reservoir with copper sulphate in the spring without taking recourse to microscopic examination or making a study to determine the actual need of treatment. This type of control is wasteful unless there is actual need at that time as the copper will not remain in solution to destroy algae which may develop at a later period.

It is well to remember that water will contain food matter which will support the active growth of only a certain number of algae. Also, there is a constant battle for the survival of the fittest. Therefore, to kill off one type of algae before necessary may pave the way for fast growth of another and perhaps more objectional type of algae.

No set formula can be given as to when it is necessary to treat a water supply for algae control. Control requirements will vary for different supplies. An operator must constantly study his reservoir as a doctor studies his patient. From study and experience he must recognize the symptoms and prescribe the correct treatment. With constant study of the thermometer, the sky, and his microscope, he will be able to apply preventive treatment and not have a sick patient on his hands that will require a drastic cure.

The upper limit for each algae that can be tolerated in a particular supply must be determined. Then when the algae are increasing in numbers and reach the predetermined limit, and temperature is not changing favorably, it is time to treat. It is not essential or economical to treat a supply until these limits are reached.

Whenever any objectional algae are present in a supply and temperature is favorable to growth, daily microscopic examination is a must. With conditions right, the increase in algae count can be phenomenal.

After deciding when it is necessary to treat a supply, the next factor to consider is the amount of copper sulphate to use in treating.

Many Factors Govern Doses

In regard to the question of the amount of copper sulphate necessary to use in treating a supply, Dr. Hale[8] states, "Experience differs with waters of different composition, with temperature and with the amount of organism. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time."

Therefore, it is a waste of chemical to apply an insufficient amount, just as it is a waste to apply an excess amount.

According to the table based on data by Moore and Kellerman, Whipple and others[6] it will be noted that in many instances, more than one dosage rate of copper sulphate treatment is given for the same organism, as Aphanizomenon 1.0 to 4.2 lb per mil gal. If the supply should be treated for Aphanizomenon with 1.0 lb of copper sulphate crystals and 4.2 lb per mil gal should be needed, the

1.0 lb per mil gal treatment would be wasted as the 4.2 lb per mil gal must be applied at one time. Likewise if the 4.2 lb per mil gal were used and one pound would do the work, then 3.2 lb per mil gal would be wasted. Thus, this table must be tempered with experience as to the chemical characteristics of the water, the temperature, and the type of organism on hand.

With this method there is always uncertainty as to the outcome of the treatment, as variation in the type of organism and composition of the water will change the amount of copper sulphate necessary to remove the algae. Furthermore, when a treatment is effective, an operator does not know if he has added an excess amount of algicide and thereby wasted some of the chemical.

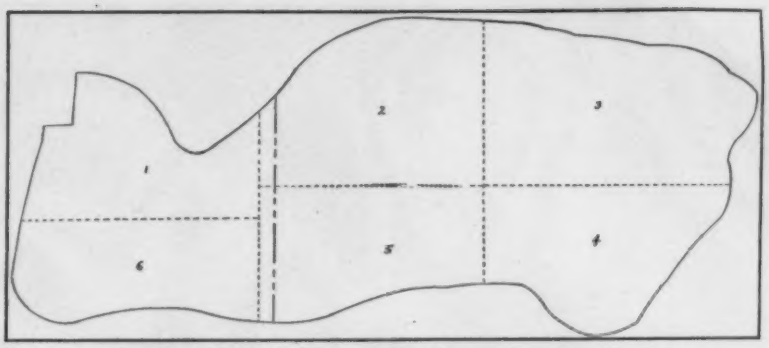
No Fixed Dose Possible

Copper sulphate is used in many plants in the form of continuous application. In a paper by Paul Weir[7] on this method of algae control, the following statement appears: "Microscopic examinations and threshold odor tests are important in attaining efficient application and control. *There is not one fixed dosage of copper sulphate suitable for any one condition,*" (italics by author) "but, generally speaking, an application of two to ten pounds per mil gal of water will be found effective in the elimination of the most objectional microscopic growths."

According to Whipple[8] the amount of copper sulphate to use in treating a supply depends on seven factors:

1. The kind of algae to be destroyed.
2. The amount of organic matter present.
3. The hardness of the water.
4. The carbonic acid content.
5. The temperature of the water.
6. The species of fish present.
7. The amount of water to be treated.

Much of the author's experience with algae control was obtained at the Canoe Brook Reservoir of the Commonwealth Water Co. located in Summit, N. J. While chemist for that company, the author devised a simple, practical laboatory test to determine the amount of copper sulphate necessary to use in treating a supply of water regardless of its temperature and composition, and, within certain limitations, regardless of the type and amount of organism present. This test, which became known as the "D.M. Test" after the author's late father, David Monie, who spent his entire working lifetime in the water works business, has been used successfully for the past fifteen years.



DIAGRAMMATIC sketch of Canoe Brook Reservoir—Summit, N. J.
Dotted lines show how reservoir is sectioned for purpose of sampling water and applying copper sulfate in proportion to water depth and algae concentrations.—During algae growing season each section is sampled daily for microscopic examination.

The D. M. Test

It was found that the addition of certain amounts of copper sulphate to water containing algae resulted in an increase in the alkalinity. It was further observed that the amount of copper sulphate needed to bring about this increase in alkalinity was the correct amount to use in treating. After much experimentation the following test was developed.

The equipment and chemicals necessary for the test are:

a. Six 50 ml. Nessler tubes.
b. A copper sulphate solution of a strength so that 2 ml added to a liter of water equals a copper sulphate treatment of 1.0 lb per mil gal.
c. Phenolphthalein indicator.
d. NaOH solution, 0.01136 N.

To make the copper sulphate solution mentioned in item b, dissolve 0.6 gram of the commercial copper sulphate used for treatment in 1 liter of distilled water. Dilute 100 ml of this solution to 1 liter with distilled water. Two ml of this final solution per liter of same equals 1.0 lb of $CuSO_4 .5H_2O$ per mil gal, or 0.1 ml per 50 ml of sample equals one pound of copper sulphate crystals per mil gal.

Test Procedure

Place 50 ml samples of the water to be treated in each of six 50 ml Nessler tubes A, B, C, D, E, and F. To tube A, add 0.1 ml of copper sulphate solution (b) to equal a treatment of 1.0 lb per mil gal.; to tube B, add 0.2 ml of solution (b); to tube C, add 0.3 ml of solution (b); to tube D, add 0.4 ml of solution (b); to tube E, add 0.5 ml. of solution (b). To tube E, add 0.5 ml of solution (b). To tube F, no copper sulphate is added. Tubes A, B, C, D, E now contain, respectively, copper sulphate dosages equal to 1.0, 2.0, 3.0, 4.0, and 5.0 lb per mil gal. These samples are then mixed by corking and inverting approximately thirty times simultaneously.

To the Nessler tube F (the blank sample) phenolphthalein indicator is added. If there is a negative amount of free carbon dioxide, enough indicator is added until there is a faint but distinct pink color. Then the same amount of phenolphthalein is added to each of the other samples. The samples are compared and the tube with the deepest color is the tube containing the sample to which has been added the correct amount of copper sulphate to use in treating.

Influence of Carbon Dioxide

If there is free carbon dioxide present (and there usually is), three drops of phenophthalein are added to each of the six samples in the Nessler tubes after they have been mixed with the various amounts of solution (b) as described above. Then 0.01136N sodium hydroxide is added to the Nessler tube F (the blank sample) until there is a faint but distinct pink color. The same amount of the sodium hydroxide is then added to the other five samples and the tubes are compared for color. The deepest color will be found to be in the tube containing the sample to which the most effective and economical amount of copper sulphate to use in treating has been added.

This test is practically the same as a free carbon dioxide titration. However, in the algae test it is simpler to have both the phenolphthalein and the sodium hydroxide in dropper bottles, as the equal amounts can be easily added to the sample tubes by counting the drops. The 0.01136 N sodium hydroxide concentration is used simply because finer control can be maintained on the color. In waters with considerable carbon dioxide, 0.02272 N can be used just as effectively.

It is important to note that the tube with the deepest color is always darker than the blank sample. Therefore, at the correct dosage of copper sul-

Courtesy Los Angeles Dept. of Water and Power

CONTINUOUS copper sulfate solution feed

phate the water is more alkaline than it was prior to the addition of the salt. This result is clearly shown in the test irrespective of the fact that phenolphthalein is not a sensitive indicator. The puzzling factor of the entire test is the fact that at a certain concentration of copper sulphate dosage the alkalinity is increased, and then with an excess of copper sulphate the alkalinity decreases to approximately the same point as it was in the blank sample. Therefore, the color in the tubes rises gradually with the dosage increase, and after reaching a maximum the overdosage causes a lessening color development.

When the "D. M." test was first developed, the author used a mixing machine with liter samples instead of the Nessler tubes. However, the reaction in the test is so fast that the results can be obtained quicker with equal accuracy using the Nessler tubes.

If more than one type of organism is present in sufficient numbers, it is possible to get two or more treating points by the "D. M." test. For example, Anabaena and Aphanizomenon were present at the same time in a reservoir. The "D. M." test showed two distinct treating points, two pounds per mg. and four pounds per mg. To use two pounds per mg. would have been a mistake as only the Anabaena would have been destroyed, which would leave conditions perfect for the rapid increase of the Aphanizomenon.

It is not to be assumed that this test reduces algae control to a routine matter and does away with the necessity of having a trained operator for this type of work. It is an additional tool for the trained man to work with.

Proper Method of Copper Application

Proper distribution of the copper salt through the reservoir water is important to successful algae control. Knowledge of the first two steps for algae control—when to treat, and how much copper sulphate to use in treating—would be of no value without proper application of the chemical. For example, if a 4.0 lb per mil gal treatment of copper sulphate is necessary, then the chemical must be applied so that the water in all parts of the reservoir has received approximately the same dosage rate. The deeper parts of the reservoir must receive in proportion more copper sulphate than the shallow parts. If this is not done, some portions of the water will be undertreated and the algae not killed in these parts remain to re-seed the reservoir.

Here again, a detailed study of conditions of each reservoir must be made and the method of application decided upon after careful deliberation. In the majority of lakes the best method of application is by dissolving the copper sulphate from burlap bags or perforated boxes attached to a boat. However, in some lakes and for certain types of algae some other method of application such as spraying either a solution of copper sulphate or broadcasting the pulverizing dry salt may be more practical.

Knowledge of Reservoir Topography Important

In order to obtain proper uniform distribution of the chemical, a knowledge of the reservoir bottom topography is an important consideration. If a contour map of the reservoir bottom, is not available, one should be made. The points for preparing such a map are easily obtained by sounding from a boat, or from the ice in northern regions.

When the reservoir bottom topography is known, it is a simple matter to section the reservoir into areas of approximately uniform depth. With this knowledge it is possible to apportion the copper sulphate in treating so that equitable application can be planned and made. In deep reservoirs usually only the top twenty to thirty feet depending upon stratification need be considered in treating.

The most common method of treating is by a boat propelled by an outboard motor. The chemical is placed in two burlap bags, one on each side of the boat, suspended from frames so that additional copper sulphate can be added to the bags to keep the amount of chemical exposed to the water uniform. The strength of the treatment is regulated by the level of copper sulphate crystals carried in the bags.

The conventional strip method is used in treating. The width of strip may vary between 40 to 100 ft. The narrower the strip that will allow full treatment in a working day the better the results. The same width of strip should be adhered to regardless of the amount of chemical per treatment,

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Capacity Gallons	Diameter	Head Range	Number of Columns
25,000	18′ 0″	13′ 9″	4
30,000	18′ 0″	16′ 6″	4
40,000	20′ 0″	17′ 10″	4
50,000	22′ 0″	19′ 0″	4
60,000	24′ 0″	19′ 0″	4
75,000	26′ 0″	21′ 0″	4
100,000	28′ 0″	23′ 9″	4
125,000	30′ 0″	25′ 9″	4
150,000	32′ 0″	27′ 11″	6
200,000	36′ 0″	29′ 11″	6
250,000	40′ 0″	29′ 2″	6
300,000	44′ 0″	30′ 0″	6
400,000	50′ 0″	30′ 0″	8
500,000	52′ 0″	35′ 0″	8
500,000	55′ 0″	30′ 0″	8
600,000	55′ 0″	40′ 0″	8
600,000	61′ 0″	35′ 0″	8
750,000	61′ 0″	40′ 0″	8
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100,000	100,470	27′ 0″	23′ 11½″
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250,000	250,340	37′ 0″	31′ 7½″
300,000	300,550	42′ 0″	29′ 6″

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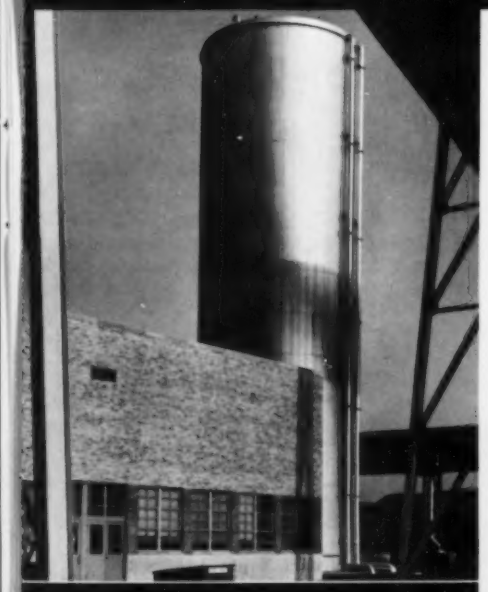

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Water supply storage tanks whose height exceeds the diameter are referred to as standpipes. When the diameter exceeds the height, they are called reservoirs. Standpipes normally provide static head to the water distribution system; reservoirs usually are intended for storage and reserve supplies. For both types of water tanks, there can be no standard sizes offered. Since the size and form depend upon local conditions and individual requirements, standpipes and reservoirs must be designed in accordance with the special needs of the users and the characteristics of the site.

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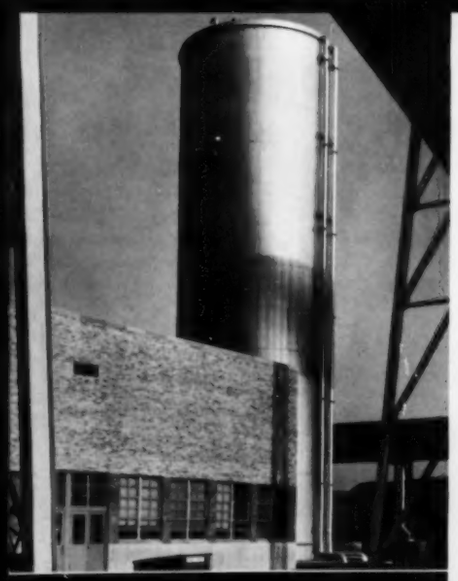

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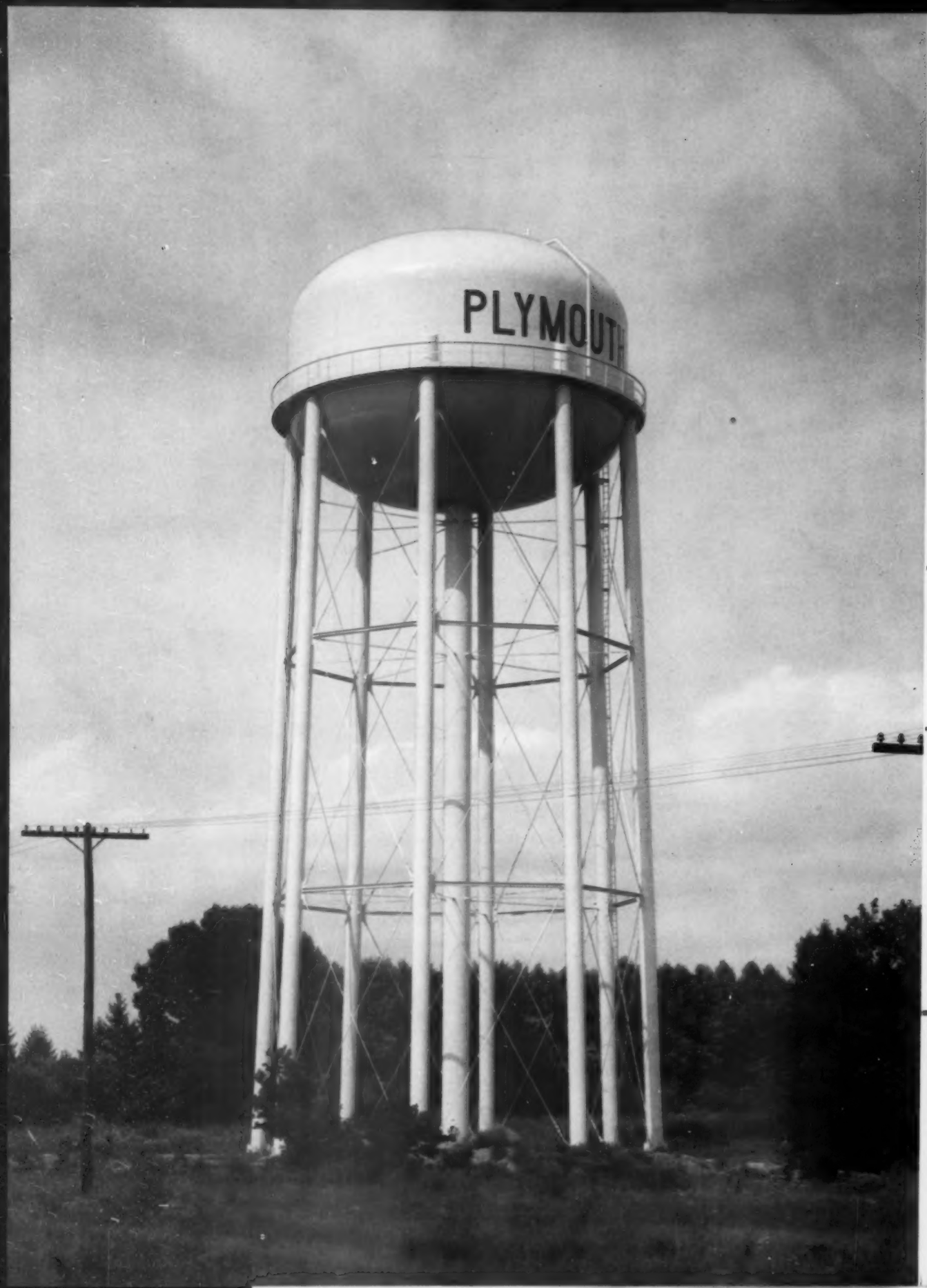

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Elevated Water Tank for the City of Plymouth, Indiana

Ralph Lentz, Water Works Superintendent
Clyde E. Williams & Associates, Inc.,
Consulting Engineers, South Bend and Indianapolis, Ind. and Lansing Mich.
Lloyd Taylor, Project Engineer
Graver Tank & Mfg. Co., Inc.,
Design, Fabrication and Erection

Type: Double Ellipsoidal Elevated Tank
Capacity: 400,000 gallons
Height of Overflow: 130 feet
Low Water Level: 100 feet
Diameter of Tank: 50 feet
Built to AWWA Specifications, except that ¼" plate was used on the roof instead of 3/16" minimum
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THE PROBLEM

A water supply system designed to serve a rural county seat of 3,838 people was woefully inadequate for today's population of 6,704 in this thriving trading center. One industry alone consumed one-third of the water. And the situation was further complicated by a disasterous flood in 1954 which polluted the city's wells located near the Yellow River. Steps had to be taken without delay to meet the problem.

THE SOLUTION

Anticipating probable population and commercial requirements by 1980, plans were developed for new wells, larger mains, and adequate pumping and storage capacity. Standards of the National Board of Fire Underwriters indicated a fire pumping formula of 150% of the flow required for normal domestic use, plus 10 hours of fire flow. The desirable storage capacity was set at 500,000 gallons, 100,000 gallons in an existing tank and 400,000 gallons in a new tank.

Graver was selected to design, fabricate, erect, paint and sterilize the new 400,000 gallon elevated water tank.

The close teamwork of the city's water works superintendent, the consulting engineers and the Graver organization speeded the elevated water tank erection so that the new water system could be put into operation in 1956.

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the amount going into solution depending upon the amount exposed to the water.

In a case where a reservoir is so large that strips over 100 ft are necessary, more than one boat should be used in treating. Other methods of "coppering" a reservoir have been described by Darby[5].

Continuous Feed

Where local conditions permit, continuous feed of copper sulphate may prove the best method of application. Especially where water passes through a chain of reservoirs.

With labor cost increasing it may be more economical to use continuous feed although it may result in chemical waste.

Conclusion And Comment

Once started on the study of algae, the result will not only be a far superior water but also a fascinating hobby.

Results of proper application of the three fundamentals of algae control ment actually destroys the organism will be most gratifying. Proper treatand does not allow, as in the case of improper treatment, half dead organisms to remain and re-seed the reservoir when conditions for growth again become favorable.

With proper treatment, results are evident within a 24-hour period after treatment, never more than 48 hours. Where results are not shown for from 3 to 7 days or more after treatment, the apparent result is probably due to other changes such as temperature as much as from the sulphate treatment.

The following library is very helpful in a study of algae:

Courtesy Los Angeles Dept. of Water & Power

MOTORBOAT method of coppering

Belt-conveyor sketched below is set to feed copper sulphate at predetermined rate in propeller stream

"Standard Methods for the Examination of Water, Sewage, and Industrial Wastes", Tenth Edition, APHA, AWWA, FSIWA.

"The Microscopy of Drinking Water" by George C. Whipple, John Wiley, New York.

"The Use of Copper Sulphate in Control of Microscopic Organisms", Phelps-Dodge Refining Co., New York

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(1) Fitch, C. P. et al "Water as a Cause of Poisoning in Animals." *Cornell Vet.* 24:1; 30 (1934)

(2) "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes," 10th Ed. APHA, AWWA, FSIWA.

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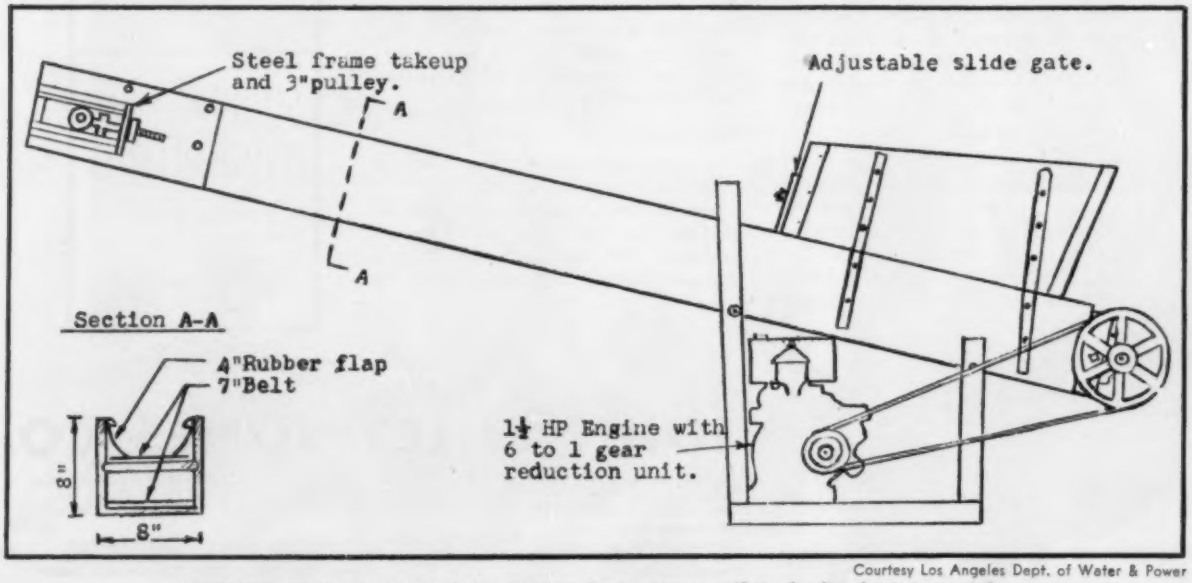
(4) Palmer and Tarzwell, *Public Works*, June, 1955, "Algae of Importance in Water Supplies."

(5) Monie and Nelson, "Algae Control," *Jour. AWWA*, April, 1941.

(6) Hale, Frank E., "The Use of Copper Sulphate in Control of Microscopic Organisms," Phelps-Dodge Refining Co., New York.

(7) Weir, Paul, "Copper Sulphate in the Water Purification Plant," Water Works & Sewerage, May, 1939.

(8) Derby and Townsend, "Reservoir Treatment by Improved Methods" *Water & Sewage Works*, June, 1953.



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SPECIFICATION sketch for belt-conveyor type copper sulfate feeder (not to scale).

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You save searching time, too, because you have a *single* convenient and dependable source for *all* your Chlorine products—liquid Chlorine, Calcium Hypochlorite, and Sodium Hypochlorite.

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Development Engineer, Omega Machine Co.
Div. of B-I-F Industries, Inc., Providence, R. I.

CHLORINE dispensing equipment is designed to control, measure and apply chlorine in the *gaseous* phase. Serious difficulties arise when attempting to secure accurate metering of *liquid* chlorine. The following statements apply generally, and reveal important reasons for designing equipment to handle gaseous chlorine:

1. Chlorine in the gas phase lends itself readily to constant pressure control.
2. Chlorine gas feed may be controlled either manually or automatically.
3. Gaseous chlorine may be metered with either visual or orifice type flow meters, with or without recording instruments.
4. Chlorine gas is readily diffused into a liquid medium at the point of application.

Operating Principles

Equipment for dispensing gaseous chlorine is designed to utilize the principles of pressure (direct) feed or of vacuum feed. The dispensing apparatus is connected either to the outlet valve of a cylinder standing vertically (Fig. 1), to the upper outlet valve of a horizontal ton container, to the gas valve of a single unit tank car, to the outlet regulator of a vaporizer, or to a valve located in the chlorine gas piping system.

The accuracy of a chlorine gas metering system relies basically on constant temperature and pressure conditions. The piping system delivering chlorine gas to the measuring device must be free of loops or pockets and avoid areas of low temperature, such as windows and cold walls. It is desirable to protect chlorine gas lines against temperature changes by insulating the piping system where necessary. Many operators install pressure controlling devices adjusted to maintain pressure within the temperature range where chlorine will not reliquefy in the chlorine piping system.

It is suggested that a check of injector operation be made each time a vacuum chlorinator is placed in service. It would appear obvious that if an injector will pull air through the vent lines, for example, it will remove chlorine gas.

All types of chlorine feeding devices are connected to the chlorine piping system in such a manner that chlorine flow may be valved off when the feeder is out of service (Fig. 2).

Vacuum Feed of Chlorine

(Visible Vacuum Type)

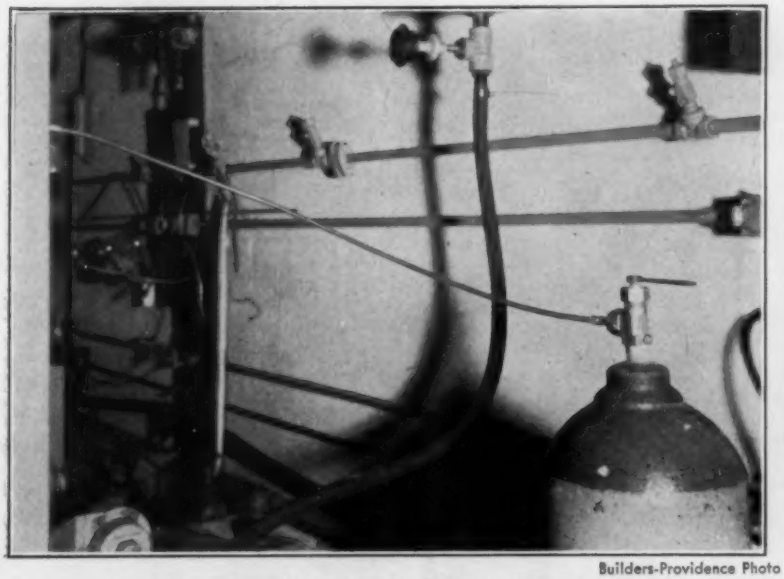
Feeders of the visible vacuum type are characterized by a glass bell jar which encloses the chlorine pressure reducing valve, metering orifice, and vacuum relief float; it may or may not enclose a calibrated feed rate tube. Chlorine is confined within the bell jar by means of a water seal maintained by an auxiliary water line. Two chlorine feeders of the visible vacuum type are illustrated in Fig. 3.

Chlorinator

As the name implies, chlorine may be fed by a visible vacuum Chlorinator* only when a condition of partial vacuum exists within the bell jar, and when all valves in the chlorine piping system are open. Pressure less than atmospheric is maintained within the bell jar by means of a water operated injector. The injector also removes chlorine at a rate dependent upon the metering orifice size and the amount of negative pressure within the bell jar.

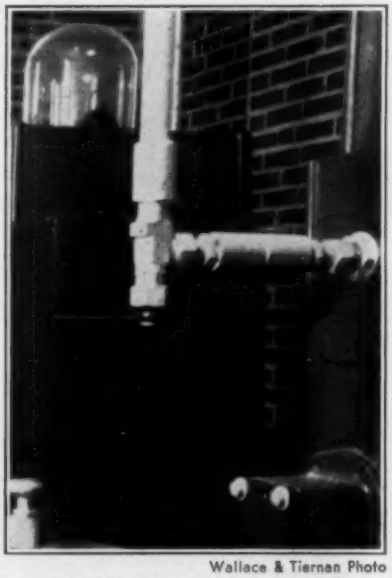
Formerly, Research Chemist, The Chlorine Institute, Inc., New York, N. Y.

*Product of Wallace & Tiernan Co., Inc., Newark, N.J. The term is also applied to a product of the Chemical Equipment Co., Los Angeles, Calif.



Builders-Providence Photo

Fig. 1—CONNECTION of chlorine feeder to chlorine cylinder
Flexible tubing conveying gas should slope upward from the cylinder.



Wallace & Tiernan Photo

Fig. 2—VALVE in chlorine supply line
Union coupling connects line to feeder.

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HTH GRANULAR

The following outstanding properties of HTH have gained wide acceptance for the product by water works operators and others using HTH in water treatment: dependable strength of at least 70% available chlorine, high stability that maintains the product at full strength even after months of storage at summer temperatures, low calcium chloride content that eliminates hygroscopic tendencies, rapid and complete solubility of the active ingredient in water.

The available chlorine in HTH is in the form of true calcium hypochlorite, which is $Ca(OCl)_2$. When consideration is given to the light-weight, non-returnable containers in which HTH is shipped, its available chlorine per pound of gross weight exceeds that of liquid chlorine in the 100- and 150-lb. cylinders. Moreover, its use involves none of the hazards that attend the handling and use of liquid chlorine. It is little wonder, therefore, that water works men avail themselves of this convenient, safe source of available chlorine wherever practicable.

The 5-lb. cans of HTH Granular, packed 9 to the case, are particularly convenient for sanitization of newly laid pipelines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypochlorination of water supplies, the 100-lb. drum of HTH Granular may be a more economical unit. In determining the more desirable package, however, consideration should be given to the advantage of keeping a product not immediately needed in sealed 5-lb. cans rather than in a 100-lb. drum that is frequently opened.

HTH TABLETS

For convenient handling in many water treatment applications, HTH is also available as HTH Tablets. This product is simply HTH in the form of compressed, easy-to-handle tablets which dissolve slowly and provide a continuous source of available chlorine over an extended period of time.

HTH Tablets are made wholly of dependable HTH and contain 70% available chlorine—the same as the time-tested granular product, HTH Granular. The tablets are stable and dust-free and thus offer an exceptionally safe and convenient means of handling, measuring and storing available chlorine. HTH Tablets are packed in 100-lb. drums and in cases of twelve 3¼-lb. cans.

HTH TABLET HYPOCHLORINATOR

By use of the HTH Tablet Hypochlorinator the convenience offered by HTH in tablet form can be combined with accurate metering and feeding of hypochlorite solutions. This equipment, specifically designed by Mathieson to dissolve HTH Tablets and to dispense the resultant hypochlorite solutions, provides a convenient and efficient method of feeding available chlorine at rates which can be accurately controlled and quickly varied to cover a wide range of operating demands.

The HTH Tablet Hypochlorinator is of practical design, compact construction, and attractive appearance; it is easy to install and very simple to operate. Moreover, HTH Tablet chlorination eliminates all measuring and weighing operations, and requires no preparation of stock solutions. The HTH Tablet Hypochlorinator is engineered to give long-time reliable service. Initial cost is low, and since the unit operates with no moving parts, maintenance and upkeep expenses are almost negligible.

HTH Tablets and the HTH Tablet Hypochlorinator can be applied successfully and economically in most cases where continuous chlorination is desired. Such uses include chlorination of industrial wastes, industrial sewage, potable water, ponds, swimming pools and spray towers, and the feeding of hypochlorite solutions in dairies, canneries, bottling plants and other food and beverage plants.

SODIUM CHLORITE

Chlorine dioxide (ClO_2), is produced at the point of use by the interaction of chlorine and sodium chlorite ($NaClO_2$). The reaction takes place in a simple mixing chamber or solution generator, and the reagents may be (1) solutions of chlorine and sodium chlorite or (2) solutions of HTH, acid and sodium chlorite. The dilute chlorine dioxide solution thus formed is fed directly into the water for taste and odor control and for disinfection.

Mathieson Sodium Chlorite Technical is a dry, flaked material containing 130 per cent available chlorine. It is non-hygroscopic, extremely soluble in water and very stable both in dry form and in solution. Packed in 100-lb. drums and 25-lb. pails.

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Chlorine gas is, therefore, mixed with water at the injector, and the mixture flows to the point of application through rubber hose or other materials resistant to chlorine water. The volume of water required to operate the apparatus may be minimized by correct sizing of injector throat and tail piece, as well as by proper feeder selection.

All those components of the visible vacuum chlorinator that are exposed to moist chlorine are constructed of corrosion resistant materials. Preventive maintenance is indicated, however, in the interests of long and economical service. As one would expect, chlorine within the bell jar takes on moisture from tray water used as a seal, hence good practice would involve removal of chlorine from the bell jar when taking a feeder out of service for any reason. This is accomplished by closing the valve on the chlorine supply line allowing the injector to continue in operation. Reduction of the gas pressure on the water seal surface will permit air to be drawn in through the vacuum relief line. Sufficient time should be allowed for complete chlorine removal from the bell jar, since minute amounts of moist chlorine exert great corrosive action.

In maintenance of the equipment, special attention should be given to the chlorine pressure reducing valve. Free movement of the ball float can be assured by preventing excess scale formation on the valve and seat. Extreme care must be exercised in cleaning this valve, so that the valve stem and seat are not damaged. Bell jar surfaces should be kept clean to permit visual examination of the several important items discussed above. Screens provided in the inlet piping should be cleaned regularly. The advantage of duplicate installations may be readily seen when continuous chlorination is mandatory, since one machine may be removed from service for either routine or emergency maintenance service.

The visible vacuum chlorine feeder may be easily adjusted for feed rate, but the simplicity of the operation may be improved by a preventive maintenance schedule. Changes in feed rate are accomplished by raising or lowering a column of water which alters the rate of chlorine removal from the bell jar through the metering orifice tube. The device used to determine the height of the water column is referred to as the "adjustable riser." A silver tube, it is free to move through a packing gland, which must fit closely to prevent water or air leakage. The riser will move freely if the tube is kept polished and if gears and pivots in the adjustment mechanism are properly lubricated.

Experience will indicate what spare parts are essential to insure continuous availability of installed equipment. It is suggested the following items be stocked as basic to a spare parts inventory: vacuum relief float, bell jar, chlorine pressure reducing valve and float, orifice tube, metering tube, adjustable riser, injector throat, injector tail piece, packing and assorted gaskets.

Vacuum Feed of Chlorine

Visible Flow

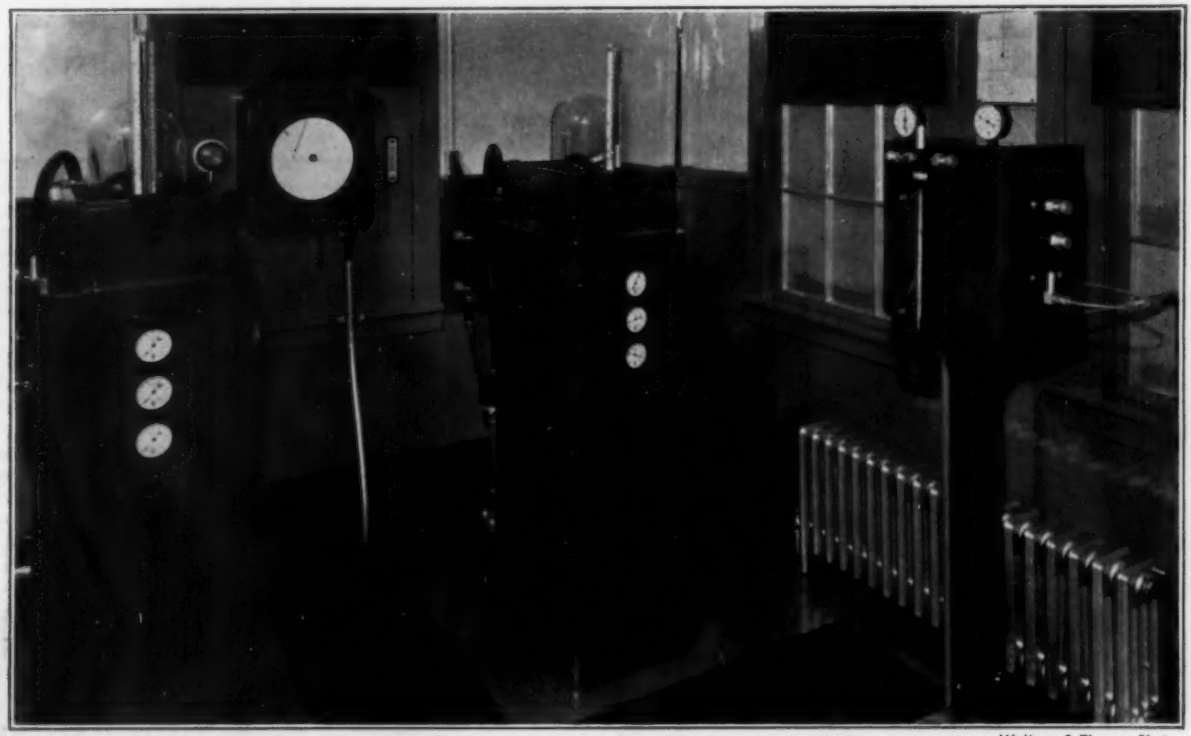
Chlorine feeders of the visible flow type are characterized by the visible flow of dry chlorine gas through a rotameter, and by mixing the gas with water at an injector. The apparatus is connected to the chlorine piping system in such a manner that chlorine flow may be valved off when the feeder is out of service. Chlorine may be fed only when conditions of partial vacuum exist within the equipment and when all valves in the chlorine piping system are open.

There are several dispensers of this type presently available to the sanitation field. The basic principles of their operation will be discussed.

Chlorinizer

The Chlorinizer* utilizes the vac-

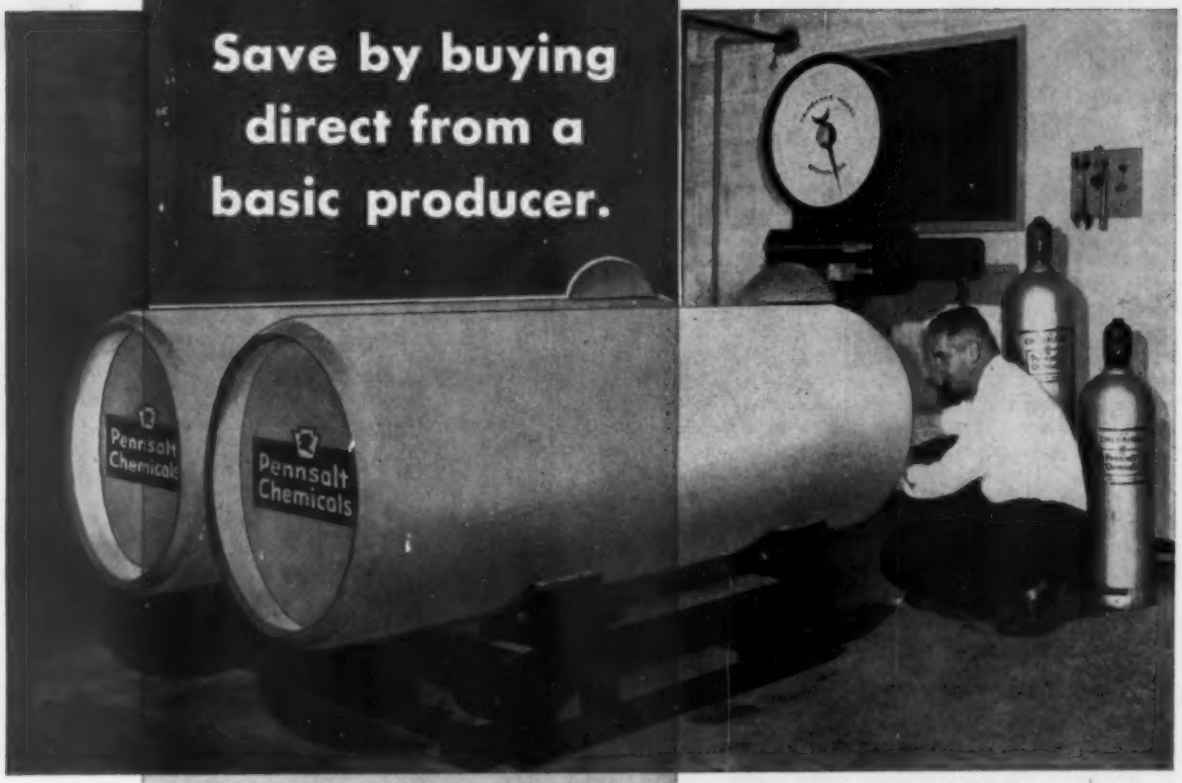
*Product of Builders-Providence, Inc., Providence, R.I.



Wallace & Tiernan Photo

Fig. 3—CHLORINATORS, two visible vacuum type chlorine feeders, and an ammonia feeder
Compact installation in the headworks of the Tacoma, Wash., Water Dept.

Save by buying direct from a basic producer.



Mr. Harry S. Fisher, Pennsalt Technical Service Engineer, inspecting ton chlorine container installation at City of Eugene, Oregon, chlorination station.

Many municipal, co-operative, and private water systems buy chlorine and other water and sewage treatment chemicals direct from PENNSALT for the simple reason that they save money by buying direct and taking advantage of Technical Service assistance.

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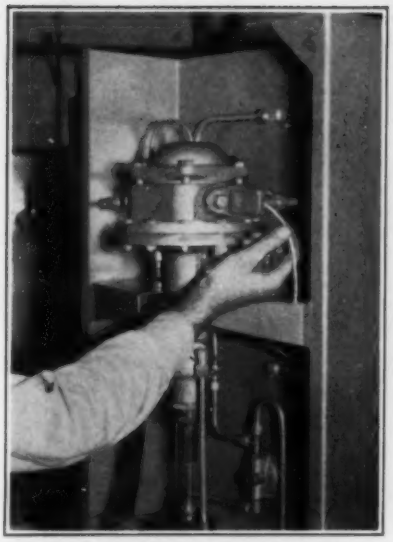


Fig. 4—SPRING-LOADED chlorine valve
Gas metering orifice being cleaned.

Builders-Providence Photo

Fig. 5—CHLORINIZER rate setting by manual control
Gas flow is visible in calibrated rotameter type metering tube.

uum induced by an injector to maintain a continuous flow of dry chlorine gas through a fixed metering orifice, rotameter, and bell jar. The chlorine gas is subsequently mixed with injector water for delivery to the point of application. Dosage control is accomplished by adjustment of a rate control valve which alters the pressure induced on the spring-loaded chlorine control valve (Fig. 4).

The control valve is in two sections, separated by a flexible tantalum diaphragm. The upper section, which reduces the chlorine gas pressure from relatively high to a partial vacuum, contains a needle valve upon which dosage control depends. The lower section, which contains water under pressure, provides the means by which the needle valve is adjusted. Any alteration of pressure in the lower section is transmitted by means of the flexible tantalum diaphragm to the needle valve in the upper section. The rate valve is controlled as illustrated in Fig. 5.

A calibrated rotameter type metering tube and float provide a visual means of flow observation. The metered chlorine gas remains dry until it passes into a bell jar, still under vacuum conditions, for delivery to the injector.

The bell jar mentioned above serves several useful functions: it encloses the metered gas, contains the chlorine gas draw-off pipe and a float-operated vacuum release which limits the amount of vacuum induced. The bell jar is suspended on a rod from the lower section of the chlorine control valve mentioned above, in such a manner that any interruption in vacuum conditions causes the needle valve in the upper section to react accordingly. Thus, the flow of chlorine to the metering component is stopped in the event of vacuum loss. A vent to outside atmosphere is also provided to remove chlorine vapor from the bell jar.

Routine preventive maintenance includes inspection of all threaded connections, tightening of all valve packing collars and keeping the metering tube and float clear at all times (Fig. 6).

Experience will indicate what spare parts are essential. It is suggested that following items be stocked as basic to a spare parts inventory: set of glass parts, spare rotameter tube and float, packing material, diaphragms and assorted gaskets.

Ratochlor

The Ratochlor* utilizes the vacuum induced by an ejector to maintain a continuous flow of dry chlorine gas through a rotameter type measuring tube (Fig. 7). The metered gas is drawn into the ejector supply water for delivery as a water solution to the point of application. Dosage control is accomplished by the adjustment of a rate control valve which alters the flow rate from the rotameter.

Chlorine gas enters the dispenser from the chlorine supply system at pressures depending on the surrounding temperature. Pressure reduction and vacuum regulation are accomplished in a spring loaded regulator, the vacuum and atmospheric sides of which are separated by a flexible plastic diaphragm. Since the conditions of vacuum are closely regulated, chlorine gas is measured, then passes through the adjustable rate valve for delivery to a second regulator which has as its function the maintenance of a constant flow rate for any manual setting of the rate valve.

An atmospheric venting system is built into the apparatus to remove chlorine vapor from the internal system to outside atmosphere. Diaphragm failure in the spring loaded vacuum regulating device mentioned above will immediately shut off the gas flow. A pressure relief valve is included in the ejector assembly.

In the interests of metering accuracy, a clean metering tube and float are of basic importance.

Items basic to a spare parts inventory will be learned from experience; however, a spare rotameter tube and float, diaphragms and assorted gaskets should be on hand at all times.

Sterelator

In the Sterelator*, chlorine gas enters the upper valve chamber of the chlorine gas regulator and shut-off valve where pressure is reduced from that existing in the chlorine piping system (Fig. 8). The gas then flows under semi-vacuum conditions into the metering system through a throttling valve.

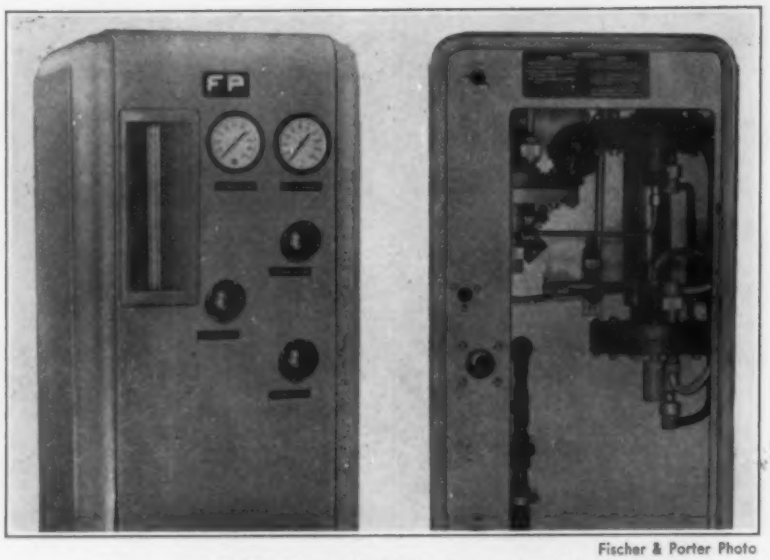
The metering component is a tapered tube rotameter type measuring device, calibrated to read directly in

*Product of Fischer & Porter Co., Hatboro, Pa.

*Product of Everson Manufacturing Corp., Chicago, Ill.

Builders-Providence Photo

Fig. 6—CLEANING the metering tube
This is good preventive maintenance.



Fischer & Porter Photo

Fig. 7—RATOCHLOR for visible flow vacuum feed of chlorine
Rate control valve alters flow rate from the rotameter.

pounds per unit of time. Following the rotameter, the metered gas flows to a vacuum tower for delivery to the suction side of the vacuum-producing injector. The gas is removed from the upper end of the vacuum tower through a suction draft tube, which also removes sufficient water to satisfy the remaining demand of injector suction. The lower portion of the vacuum tower is immersed in a float controlled, constant level reservoir, which serves as a water seal between the metered gas and the atmosphere.

Safety features of the apparatus include a positive, spring actuated shut-off at the chlorine gas regulator and an hydraulically operated vacuum breaker which provides a vent to the outside atmosphere. The vacuum breaker is connected to upper as well as the lower end of the vacuum tower.

Pressure Feed of Chlorine

Direct Feed

Direct feed equipment provides for metering dry chlorine gas and is installed in the piping system between the chlorine package and the point of application. The gas is not injected into a minor stream of water for eventual blending at the point of application; rather, the chlorine is conducted under necessary pressure conditions to the major flow of liquid being chlorinated.

The apparatus includes gauges for determining pressures in the chlorine piping system and within the device. Metering components of pressure feed devices may be either the rotameter or pressure differential (manometer) types, with provision for pressure compensation to insure measuring accuracy. Anti-flood protection should be provided to function automatically during shutdown periods or when excessive back pressure exists at the application point.

Maintenance of direct feed apparatus consists of regular inspection of the chlorine piping system, shut-off valve, gauges, control valve and all connections. The metering device should be kept clean at all times.

Everson Mfg. Corp. Photo

Fig. 8—STERELATOR chlorine feeder, visible flow vacuum type
A rotameter is the gas measuring device employed.

Cleaning Procedures

It should be noted that the removal of chlorine residue from hard rubber floats and other portions of the feeding equipment is included in good housekeeping practices. While no perfect solution to the cleaning problem has been reported, the use of certain solvents—methanol (wood alcohol) and carbon tetrachloride—is suggested in addition to water and the time-tested scraping technique.

Caution must be exercised when employing the organic solvents, since

a temperature rise (particularly when using methanol) may occur during the operation. The following procedure is recommended when cleaning chlorine feeder parts: Wash with water to remove water soluble material; wash next with a recommended solvent, using care to avoid breathing any fumes released; thoroughly rinse free of solvent and dry completely before replacing the parts for service.

It is pointed out that use of methanol and carbon tetrachloride as cleaning solvents avoids the possibility of forming undesirable chloro compounds if insufficient rinsing is accomplished since methanol oxidizes to carbon-dioxide and water and carbon tetrachloride is the product of chlorinated methane; however, good practice indicates thorough water rinsing followed by air drying.

Common practice has been to scrape the dry residue from the outer surfaces of hard rubber components of feeding machines. Sharp instruments, such as knives or razor blades, together with abrasives, sand paper and steel wool must be used carefully to avoid possible injury to the equipment. When the scraping procedure is followed, caution should be observed to avoid inhaling the dusty residue.

Chlorine Hydrate

The formation of chlorine hydrate in some chlorine feeders, commonly referred to as "chlorine ice," results from high concentrations of chlorine subjected at reduced pressure to temperatures below 49.2° F. Faulty feeder operation or poor chlorine quality are not the cause of this condition, which may interfere with metering accuracy or adequate vacuum relief. The solution to this problem is to raise the temperature of the affected area or warm the influent chlorine gas. By far the safest method is to warm the affected area by adding warm make-up water. It is possible to warm the influent gas, but extreme caution must be exercised; guidance in this operation should be obtained from the chlorine supplier or equipment manufacturer.

Automatic Control

Chlorinating equipment has been developed which enables automatic control of chlorine dosage. Accessories are available which will vary the feed automatically proportional to the flow of the liquid being chlorinated, or will effect intermittent chlorine dosage where desired.

General Suggestions

Close attention should be paid to all portions of the chlorine piping system and feeding equipment for evidence of gas leakage. Inspection should be made of all threaded connections and valves, and should include prompt corrective action for leaks. Packing glands tend to dry out and should be replaced at regular intervals.

Leakage in water piping and valves should also be eliminated, if for no other reason than conservation. External condensation on water lines can be the cause of expensive pipe replacement and would indicate the need for protective paint application.

Vents to the out-of-doors are frequently overlooked in routine maintenance schedules. It should be noted that vents to the atmosphere constitute important safety devices. The possibility of water entering vent lines, thus serving as a trap, must be eliminated. Freezing or plugging with foreign material must be avoided.

R-212

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Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

W&T Series A-711 V-notch chlorinator

The W&T Series A-711 chlorinator features a new concept in chlorine flow control—the V-notch Variable-Orifice. This provides wide range adjustment and excellent reproducibility of chlorine flow with substantially linear flow readings on a rotameter feed rate indicator. The Series A-711 chlorinator is adaptable to any type of chlorinator control. Corrosion resistant materials, which include fiberglass plastic for the chlorinator cabinet, are used throughout to assure long life and maintenance free operation.

W&T Series A-711 V-notch chlorinator

THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochlorite in solution form and is furnished in three types:

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day.

Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

WT SILACTOR ®

The WT Silactor (pronounced SILL-actor) provides a system for the continuous production of activated silica with chlorine. Raw materials—chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

WT Silactor

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For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

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Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

Amperometric Titration and Chlorine Residual Recording

by F. MORLEY WEIR

Division Engineer, Wallace & Tiernan Co., San Francisco, Calif.

THE FACT that chlorine residuals can be quickly and conveniently determined has been one of the factors that has contributed to the widespread use of chlorination in the water works field.

Residual Determination

Of the older methods used, the most popular have been the orthotolidine test (known as the OT test), the orthotolidine arsenite or OTA test, and the starch-iodide test. In the OT test, orthotolidine reacts with the chlorine in the sample to produce a color which is dependent on the amount of residual chlorine present. This color is then compared, by means of a comparator, with a graduated set of known standards to determine the value of the residual. The resulting answer is a measure of the total chlorine residual present.

The OTA test is essentially a refinement of the OT test in which sodium arsenite is added to the test sample within five seconds after the OT has been added to the sample. The sodium arsenite neutralizes the combined chlorine residual present, the reading giving the value of free available chlorine residual. By use of this method in conjunction with the test without sodium arsenite, it is thus possible to determine free available chlorine residual and by numerical difference the combined chlorine residual.

The starch-iodide test, involving titration to a colorimetric end point, is not particularly suitable for chlorine residuals in the range normally encountered in water works practice and is generally employed only where the residuals are greater than 10 ppm.

Although the colorimetric test based on orthotolidine will continue to play an important role in chlorine residual determination, there are certain inherent sources of error. Among the possible errors are false color due to manganese or iron, turbidity of the sample, variation in light source, simultaneous development, fading of the color, fading of the permanent standards, and human error.

Newer Methods

The two most recent methods of residual determination are amperometric titration and direct residual recording. Both of these methods eliminate the mechanical or chemical sources of error and minimize the possibility of human error.

The development of these present types of equipment was interrelated. The first approach to the problem of residual recording was on a colorimetric basis, in which a machine was developed to do the test, utilizing orthotolidine. A successful machine was developed, but it was necessarily quite complicated and not particluarly suited to the average water works installation. It might be pointed out that seven or eight of these machines were in use for many years by the City of Los Angeles, where they were used to control the dosage rate on volumetrically proportional chlorinators.

Due to the inadequacies of the colorimetric process itself, the Wallace & Tiernan research program was directed along electro-chemical lines, with various types of potential cells and polarization cells being tried. During the developmental stages of this equipment, it soon became apparent that calibrating electro-chemical devices by use of the orthotolidine method was unsound, as the electro-chemical methods were much more sensitive than the colorimetric method. As a result of the need for a more accurate determination, the present amperometric titration method was developed.

With this new calibration method available, work was continued on the residual recording devices. It was found that some polarization cells could be constructed that would work reasonably well in the laboratory, and on specific types of water, but would not perform very well under actual field conditions. Continued work on the potential cell finally produced a very satisfactory piece of equipment that is described in more detail later in this article.

Amperometric Titration

Amperometric titration depends on the ability of a reducing agent, phenylarsene oxide, to react quantitatively with free chlorine or free iodine over a wide pH range, without reacting with combined chlorine. In the titrator itself is a platinum-silver cell, which produces a current due to the oxidizing action of free chlorine or free iodine.

This current is indicated on a microammeter connected in series with the cell. As phenylarsene oxide solution is added in small increments to the continuously stirred sample, the current decreases and the meter needle deflects down scale. The end point of the titration is reached when additional phenylarsene will produce no additional deflection. The normality of the phenylarsene oxide is selected to give a direct reading in parts per million of chlorine from the quantity of phenylarsene oxide used.

Combined chlorine residual can be determined by the titrator because the cell is also sensitive to free iodine. A small quantity of potassium iodide is added to the sample to be titrated. The amount of free iodine liberated is directly proportional to the amount of the combined chlorine present, and is determined by the same procedure.

It might be pointed out that a further refinement in determining the type of chloramine is possible with this instrument, due to the fact that at pH 7 only mono-chloramine will release iodine from potassium iodide, whereas at pH 4 both mono-chloramine and di-chloramine will cause the release. Accordingly, by selecting the points at which various buffer solutions and potassium iodide are added, it is possible to determine in one sam-

ple the free chlorine, di-chloramine, and mono-chloramine, with, of course, the total combined residual being the sum of all three.

Since the end point of the titration is determined by observing whether or not the pointer of an electric meter moves, there is very little human error after a small amount of practice. Turbidity, manganese and iron do not affect the readings, and the phenlyarsene oxide solution is quite stable at the normality used. If desired, it is possible to obtain accuracies within 0.01 ppm.

Residual Recording

The present residual recorder is the result of a development program that extended over a period of more than 15 years and which involved numerous trial cells in the laboratory, a mobile trailer laboratory, and many trial installations. There was finally developed the present arrangement that makes use of a platinum alloy-copper cell with the electrodes mounted coaxially with the sample water flowing through the cell continously. This has proved to be a very successful piece of equipment, and at present there are approximately 300 of these in use.

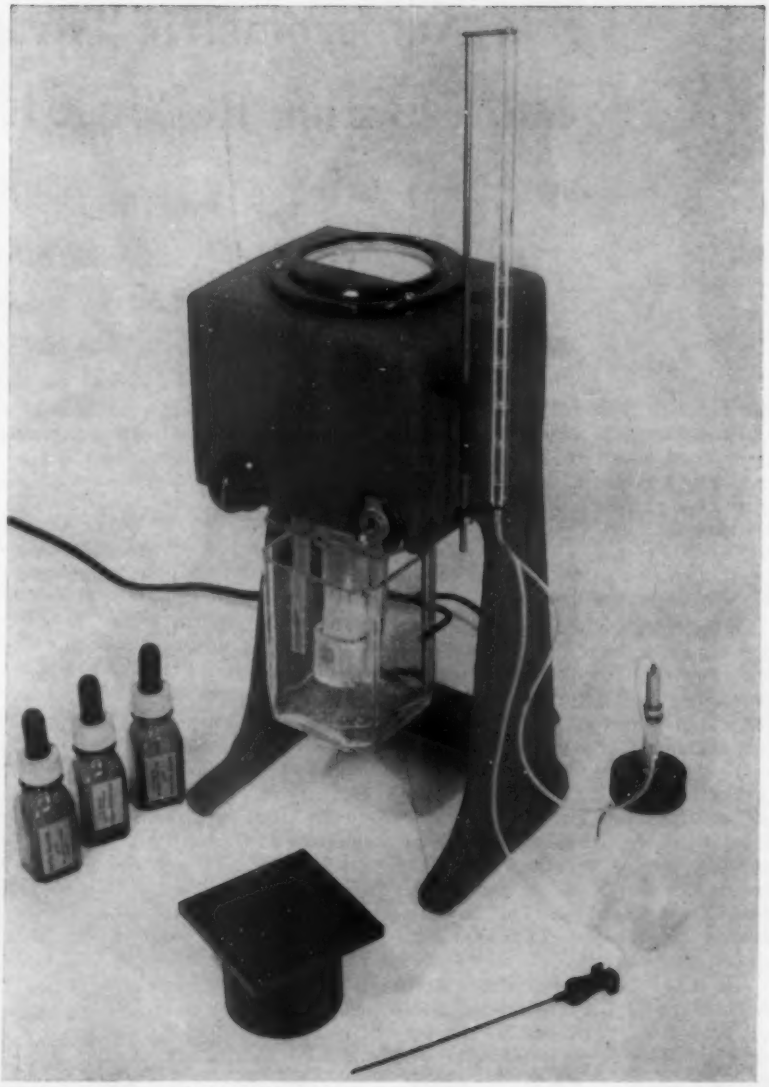
The characteristic of this cell is to produce a small DC current which is directly proportional to the amount of free chlorine or free iodine present in the sample. This current is measured by a recording micro-ammeter with a chart printed in terms of parts per million of chlorine. Provision is made to continuously recirculate a small quantity of abrasive, which prevents fouling of the cell unit by slime or chemical deposit.

The cell has both a temperature coefficient and a pH coefficient. The effect of temperature on the change in current is mathematically predictable and is compensated for by a manual temperature setting incorporated in the recorder circuit. Since the coefficient of pH is not mathematically predictable, the sample water is stabilized to a known pH by the addition of a small amount of continuously pumped buffer solution.

As in the case of the titrator, the recorder can be set to record either free chlorine or total chlorine. When a free chlorine residual record is desired, a standard buffer solution is used. When total chlorine is to be read, potassium iodide is added to the buffer, and since the cell reacts to both free chlorine and free iodine, the actual reading represents the total amount of chlorine residual present.

The hydraulic section of the equipment has a suitable flow regulator, a sample tap, and is equipped with either a manual or a motor-driven mechanical filter. Incorporated in the recording instrument is a set of alarm contacts. These contacts can be arranged to give a single alarm for either high or low residual, or to give separate alarms indicating whether the reading is too high or too low. The position of the contacts is readily adjustable to give a signal at any point along the full scale.

The recorder is designed so that it may be calibrated to any full-scale range that best suits the conditions at a given installation. Standard charts available have a range from 0 to 1, 0 to 2, or 0 to 5 ppm. Calibration procedure is to make the chart reading correct at two values of residual. One of the values used is zero, the other being the residual in the water arriving at the recorder installation. It is not necessary to have zero chlorine residual water available for the zero determination, as this condition can be simulated by turning off the water supply to the cell. Normal residual in the sample water is measured on the amperometric titrator furnished with the residual recorder.



AMPEROMETRIC TITRATOR is used for very accurate laboratory determination of chlorine residuals and for calibration of residual recorders

Application

The present uses of both the titrator and the recorder are quite numerous. The titrator is part of any well-equipped laboratory, where it can be used in any tests requiring accurate determination of chlorine residuals. Such tests include the chlorine demand of water, the type and quantity

of residual chlorine available, and the residual level in taste and odor threshold tests. In addition, it is used in conjunction with the residual recorder as a calibration instrument.

The residual recorders are quite flexible in their installation. For example, the determining cell and the recorder can be separately located up to several miles apart. In addition, it is perfectly feasible to have a remote indicator or recorder that repeats the residual shown on the initial recorder.

The recorders are available in two different arrangements. One style is cabinet mounted for a permanent installation. The second consists of three smaller readily portable units, which bolt together to form a panel. This latter type is used primarily for recording on the distribution system.

The residual recorders have proved very useful for filter plant operation and for systems where chlorination alone is practiced. In filter plants where pre-chlorination and post-chlorination are used, sample water to the recorder can be taken after the mixing chamber, or at some point in the sedimentation basin.

Sudden increases in the chlorine demand in the raw water will be almost immediately detected and appropriate steps can be taken to adjust the pre- and post-chlorination doses. One Eastern plant that makes use of this setup was immediately alerted when the pre-chlorination residual dropped to zero. The sudden increase in demand was traced to a leaking tank of ammonia at a fertilizer plant approximately a mile up the river.

Aside from detecting unusual conditions, sampling in the clear well prior to post-chlorination can allow adjustment of the post-chlorination to compensate for varying residuals caused by variation in detention time, sunlight, and atmospheric conditions.

In systems not employing filtration plants but making use of chlorination, the recorder is of obvious value in furnishing a permanent record of the chlorine residual carried into the system. Such a record gives an overall measure of the efficiency of the chlorination program. As such it would be valuable in discussion with the Health Department responsible for the system. In the event of litigation based on waterborne disease, this record could be the star witness. It would also serve as a sound basis for administrative evaluation work and future planning of improvement projects.

Since the value is recorded continuously, it is easy to detect a downward or upward drift in the residual reading so that appropriate chlorination rates can be set up to maintain the proper residual. There have been very few installations of recorders made where additional knowledge of the operation or the hydraulics of the system was not secured.

Numerous cases have shown up where too much time was consumed in getting new tanks hooked up to the chlorinators, with the result that the residual dropped to zero for considerable periods of time. In one Mid-Western pumping and rechlorination station it was discovered that the residual dropped to zero each night about 7 o'clock, stayed down for about an hour, and then went back to normal. Careful investigation showed that the night attendant was shutting down the chlorinator while he went out of the plant for his dinner.

Patterns of hydraulic flow can sometimes be determined by use of a residual recorder, where practically no other method would be satisfactory. In one particularly long pipeline it has been found that it takes 26 hours for the water to go from a lake pumping and chlorination station to a pumping and rechlorination station at the beginning of the distribution system. With a recorder operating directly after the lake pumping station, it is possible to correct any error in underfeed or overfeed by a suitable adjustment 26 hours later at the second station.

In grid systems or systems where the flow can follow alternate routes continuous residual recording is very useful in determining flow patterns

In addition to the uses previously indicated, there appears to be an ever-increasing field for this type of equipment. At present there are several experimental installations in both England and the United States in which the residual recorder is used to supplement proportional volumetric control. In certain highly specialized cases where the degree of sewage treatment has to be extremely high since the effluent enters a source of potable water, residual recorders would be indicated as a measure of efficiency of the sewage plant. Methods also have been developed for cyanide destruction and heavy metals removal which are based on control of the oxidation process by means of similar type cells.

Summary

In summing up, there is now available an amperometric titrator for very accurate laboratory determination of chlorine residuals and a well-proven and practical residual recorder with a multitude of uses in filter plant operation and water distribution systems.

Pulverized Quicklime for Water Softening

by D. W. JONES

Superintendent, Water Department, North Miami, Fla.

LIME in its various forms has many uses in the treatment of water. The principal ones, however, may be covered under the three headings of water softening, pH control and sterilization. Of these three, water softening accounts for the greatest quantity and the employment of lime therein usually combines all three of the uses mentioned.

Of the salts which produce the phenomenon known as "hardness" in water, the ones most commonly found are those of calcium and/or magnesium. These may be divided into two general groups: (a) those salts containing carbonates or bicarbonates, and (b) those which do not have carbonate or bicarbonate in their composition.

Hardness in water is classified, therefore, as carbonate and non-carbonate. Lime is of value in the removal of carbonate hardness only. The carbonates of both calcium and magnesium exist in natural waters. Both can be removed with lime, although the process of removal of magnesium carbonate is somewhat different from that of the removal of calcium carbonate.

In the North Miami, Florida, water treatment plant, no attempt is made to remove magnesium since the quantity of that element is insignificant. The discussion being confined to the operation of the plant in North Miami, only the use of lime in connection with the removal of calcium bicarbonate is discussed.

Calcium hydroxide, $Ca(OH)_2$, added to water containing calcium bicarbonate, $Ca(HCO_3)_2$, causes the following reaction:

$$Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2\,CaCO_3 \downarrow + 2\,H_2O$$

The $CaCO_3$ is normal calcium carbonate, is insoluble in water, forms a milky turbidity, and upon the addition of coagulants and the provision of a quiescent settling period will sink to the bottom of any container in which the solution is placed. Whereas the calcium carbonate is almost completely insoluble, no solid is absolutely insoluble in water and there will be some residual calcium carbonate in the clear water after the sedimentation of the precipitated material. This usually amounts to between 10 and 20 percent of the original total.

At North Miami the alkalinity is reduced from approximately 200 ppm in the raw water to approximately 20 ppm in the softened water. This constitutes a very satisfactory operation.

The sludge produced by this reaction constitutes a considerable item and its disposal becomes a major factor to be reckoned with in the operation of a water softening plant. There is no difference in the quantity of sludge produced between the process using hydrated lime and the process using quicklime because the chemical reaction takes place between calcium bicarbonate and calcium hydroxide in either event. No detail discussion, therefore, of the means necessary to dispose of water softening plant sludge is indicated other than to point out that the problem does exist but is in no way affected by the type of lime used in the process.

It might be of interest, however, that the calcium carbonate, which constitutes something more than 90 per cent of the total quantity of sludge, is simply a finely divided form of limestone rock and constitutes an excellent raw material for quicklime. In some plants it is burned and used again in the process. An outstanding example of this can be found in the water plant of the city of Miami, Florida. The material has little if any value apart from this except as land fill.

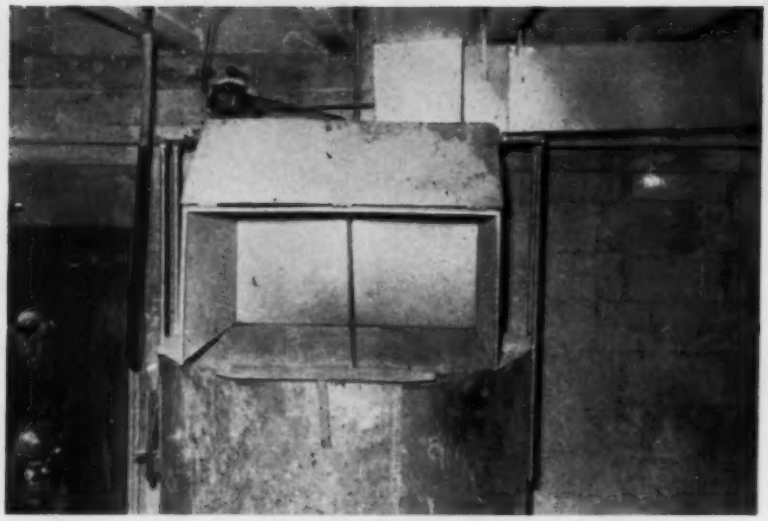
Process at North Miami

The water softening process at North Miami comprises facilities to accomplish the following principal operations:

1. Storage and feeding of chemicals.
2. Provision for chemical reaction with water and settling of sludge.
3. Filtration of the softened water.

PULVERIZED quicklime goes from bagged storage via—

PORTABLE conveyor belt to lime feeder



TOP of lime feeder hopper

4. Provision for storage of the completely processed water.

5. Provision for the disposal of the sludge produced.

A discussion of the size and capacity of the plant is essential to evaluation of the comparative importance of lime as one of the items making up the process of water production. Reference to Table 1 will show that the magnitude of the operation at present, or rather during the month of June 1954 was in the order of 3 mgd average production. The ultimate daily capacity of the plant is 7.75 mgd and there are maximum days at present which nearly reach that value.

To process this average of 3 mgd requires approximately 2 tons of pulverized quicklime and slightly more than 2½ tons of hydrated lime when that is used in place of quicklime. The cost per million gallons for the material at present prices is $18.20 and $21.10, respectively.

The use of lime in its present form was brought about largely by a sudden and unforseen change in the water requirements of the municipality. During the 20-year period between 1925 and 1945, the growth of North Miami was negligible. The water plant in use during that period was a batch-type water softening plant with a capacity of perhaps, 0.3 to 0.5 mgd.

In 1946 the first section of the present water softening plant, originally intended to provide a capacity of 1 mgd, was constructed. By the time it was ready for operation the requirements of the municipality were in excess of 1 mgd and modifications were made which permitted the expansion of the original plant to 2 mgd. At the same time, design of the second portion of the existing plant was started.

Finally placed in operation during 1951, it, together with the first section, provides for the present maximum capacity of 7.75 mgd. The first section of the present plant was designed for use with hydrated lime and its operation was completely satisfactory.

The fact that quicklime is considerably less bulky than hydrated lime and, in the form in which it is usually used in a water softening plant, considerably cheaper than hydrated lime, caused the plant designers to provide in their plans for the present 7.75-mgd plant facilities for processing of lump quicklime to use as a substitute for hydrate in the process. Funds were not available for the purchase of the equipment for the use of the quicklime at the time of the construction of the second section of the plant, consequently the use of the hydrated lime was continued.

The plant management, being progressive and desirous of taking advantage of all possibilities for improvement of the product and reduction of operating costs, decided to look into the possibilities of using quicklime without expending funds beyond the means of its financial resources. Normally the cost of providing storage, handling and slaking facilities for the use of quicklime is several times the outlay required for handling of hydrated lime.

The advantages of using quicklime, however, are considerable. The management of the plant therefore conducted research into ways and means of changing to the use of quicklime without incurring the heavy expense which would have been involved in the construction of the quicklime handling facilities originally planned.

It seemed reasonable to suppose that the rapidity with which the slaking operation might take place would be a function of the fineness of the particle size of the material being slaked. Consequently it was decided to try the use of pulverized quicklime in the same feeding facilities used for handling hydrated lime to determine what modifications might be necessary in the slurry mixing chamber to provide for effective slaking. Accordingly, a small quantity of pulverized quicklime was purchased and its use was attempted without making any changes in the feeding and mixing equipment.

All concerned were amazed to note that the operation of the plant with the pulverized quicklime, without any changes whatever to the facilities previously used for hydrated lime, was completely satisfactory. A larger quantity of the material was accordingly purchased and the use continued with the same completely satisfactory results.

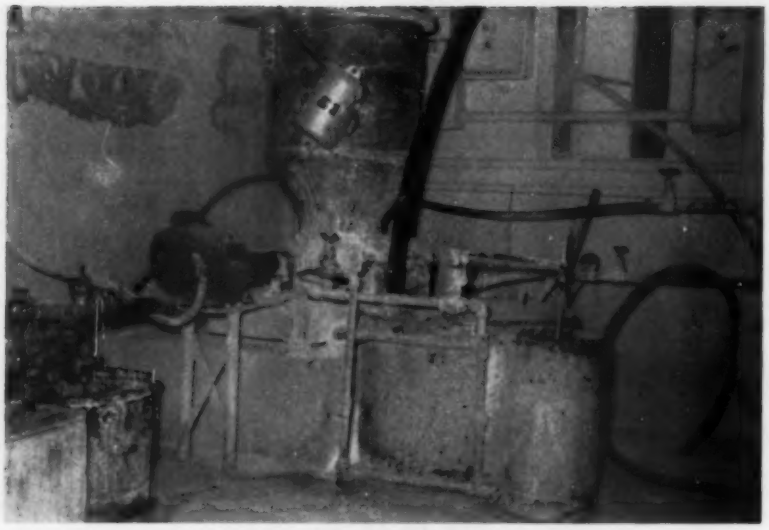
Although the cost of pulverized quicklime is slightly more than the cost of hydrated lime, the fact that there is considerably more calcium oxide present per pound in the pulverized quicklime more than offsets the additional cost. This being the case, the cost of chemicals per million gallons of water is materially less when using pulverized quicklime than when using hydrated lime.

At this point it might be well to again point out and emphasize the fact that the chemical handling and storage equipment for use with the hydrated lime is identically the same as that required for the use of the pulverized quicklime. This plant can change from one material to the other and require no adjustment to the handling devices except in the rate of feed of the material. The operator is required to change the setting of the feeder since less pulverized quicklime than hydrated lime is required per million gallons of water.

This change is a routine matter, however, since it is also required whenever a change occurs in the rate of flow of raw water. Reduction in alkalinity and hardness is identical between the two materials and there is no other difference involved in the processing of the water. There is no effect on filtration and no effect on the rate of sedimentation of the sludge produced by the chemical reactions.

From bagged storage, a portable conveyor belt carries the bags of lime to an elevated feeder hopper. The dry lime is then fed to a slurry pot for mixing with city water, the slurry being fed through a hose to the water softener reaction tank by means of a water jet pump operated by city water. A small amount of sludge from the softening process is returned to the slurry pot to prevent scaling of the

FEEDER discharges to——



MIXING POT from which lime slurry is drawn

lime slurry hose, the eductor, and other parts in contact with the slurry.

Conventional Use of Quicklime

The foregoing discussion of the use of pulverized quicklime has made comparisons primarily with hydrated lime. Actually quicklime has been successfully used in water treatment for many years. It is the purpose of the discussion in this section, therefore, to provide a comparison between the commonly followed procedure of applying quicklime with the much simpler method needed when it is used in the pulverized form.

The conventional method of using quicklime usually entails its purchase in bulk as either run of kiln, graded lump lime, pebble lime, or granulated lime. The material is normally stored in steel or concrete vertical cylindrical bins, tightly closed to prevent the possibility of becoming wet.

From the bins it is transported, either by conveyor belt or similar means, to the hoppers of dry feeding machines, from which it is fed to a slaker by means of a gravimetric feeding device (a device in which the control is actuated by variation in weight of the material rather than volume).

In the slaker, water is added as the mixture is agitated. The quantity of water is usually thermostatically controlled to keep the temperature of the mixture within allowable limits. Retention time in the mixing chamber of the slaker should be from 15 to 30 minutes. At the end of that time the slurry produced is pumped to the point of application in the water.

The slurry produced in the slaker is used in the same manner as the slurry produced in the equipment previously described. Normally there is an appreciable percentage of foreign matter present in the unslaked lime. This foreign matter is rejected in the slaker and discharged to waste. The presence of a considerable quantity of rejectable material in the unslaked lime passing through the feeder causes variations in the quality of the water being treated over which the operator has no control.

Variations in temperature of the mixture in the slaker cause variations in the available calcium oxide content of the slurry, since the slaking reaction is not completely uniform at all temperatures. This in turn affects the quality of treated water.

The foreign matter contained in the unslaked lime is frequently abrasive and causes deterioration of the mechanical equipment in the slaker as well as that used for the handling and storage of lime. This not only increases the maintenance costs, but also decreases reliability and makes for additional serious variations from time to time in the quality of the water produced.

The conventional means of storing and handling any of the grades other than pulverized presents occupational hazards which are considerably more serious than those involved with either hydrated lime or pulverized quicklime. This is particularly true in the smaller water treatment plants wherein the close supervision of safety matters is not ordinarily available.

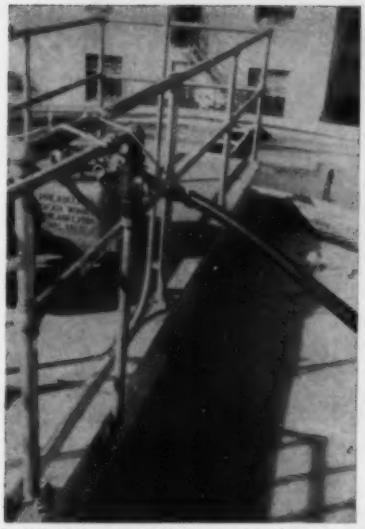
There have been instances of personnel being seriously burned in this immediate area by the overflow of the slurry from a lime slaking device. Furthermore, personnel involved in the handling of bulk quicklime are subject to skin and lung irritations caused by dust from the lime and due to frequent contact between the skin and the lime.

The quicklime is available in the unrefined state, either as lump lime or run of kiln lime at far less cost than in the pulverized condition. In very large water softening operations, therefore, use of the more highly refined material is not economically sound. If it is desired to take advantage of the much more accurate application that can be obtained from its use in the pulverized state, it would likely be desirable to install pulverizing equipment to prepare the material for use, rather than lime slakers. This would permit the proportioning of the chemical in the pulverized state with consequent much more accurate treatment.

While no actual cost data are available at present to determine which method would be the most feasible, it appears that an investigation of the possibilities of such an installation would be definitely justified when planning for water treatment undertakings which would require the use of large quantities of lime.

For plants of the size and lime consumption rating of that at North Miami and smaller, it is believed that the use of the pulverized quicklime is more desirable than quicklime in other forms and considerably more economical, as well as desirable, than the use of hydrated lime, even in plants as small as those used in soft drink bottling establishments.

Operators report that quicklime pulverized and furnished in paper bags, such as is the case in the North Miami plant, is easier to handle and causes less irritation to the person than the hydrated lime previously used. The quicklime is somewhat heavier, particle sizes are a little greater, and the amount of dust produced is very much less than is the case with hydrated lime.



EDUCTOR to softener reaction tank

Advantages of the Process

Some of the advantages claimed in connection with the use of the process previously described are as follows:

1. Advantages in connection with water softening:

(a) Brings about a reduction in cost of chemicals as compared to hydrated lime.

(b) Reduces the amount of chemical storage space required as compared to hydrated lime.

(c) Reduces the amount of dust generated in handling and thereby reduces the health hazard to personnel, involved in use of hydrated lime.

(d) Provides for much more accurate proportioning of chemicals to water than is possible with other forms of quicklime which require slaking before being used.

(e) By elimination of slaking, one of the most troublesome items of equipment involved in the use of quicklime in water softening is also eliminated, thereby improving the uniformity of the quality of the finished water and materially decreasing the risk of shutdowns of the softening plant.

(f) By elimination of slaking there is also eliminated an occupational hazard caused by occasional overflow of hot lime slurry at a temperature sufficiently high to cause serious burns.

2. Advantages in connection with other uses of lime:

All of the advantages enumerated in connection with water softening also apply to any process where lime of purity comparable to that used in water softening is used in slurry form, such as:

(a) Preparation of saturated lime water.

(b) pH adjustment of water.

(c) Manufacture of paper.

(d) Processing of certain types of prepared foods.

Summary

The water softening operation at the North Miami plant originally involved application of hydrated lime to hard well water in carefully proportioned amounts in a mixing tank wherein the resultant sludge is partially separated and from which the water is allowed to pass to sand filters, thence to storage tanks and the distribution system. This process has been in widespread use for many years and involves nothing new or unusual.

In many larger water softening plants quicklime has been substituted for hydrated lime because of its greater activity per pound and because it is less expensive in the form in which it is usually marketed. In order to use it successfully, however, it is necessary to pass it through a slaking process and to sacrifice considerable accuracy in proportioning thereby. A much larger investment is required in storage, handling, feeding and slaking equipment than is the case when using hydrated lime and the skill level of the operating personnel must be considerably higher. These factors account for the fact that the use of quicklime is usually confined to plants using more than North Miami.

A method has been discovered and applied at North Miami of using quicklime in the pulverized form, which eliminates the necessity for slaking and preserves all the advantages hydrated lime has over quicklime, plus certain additional advantages. While the cost per ton of the material is more than for hydrate, because of its greater activity per pound it costs less per unit of water treated and requires no additional investment for storage, handling, feeding or slaking equipment.

TABLE 1

Operating Data for Water Softening at North Miami Plant

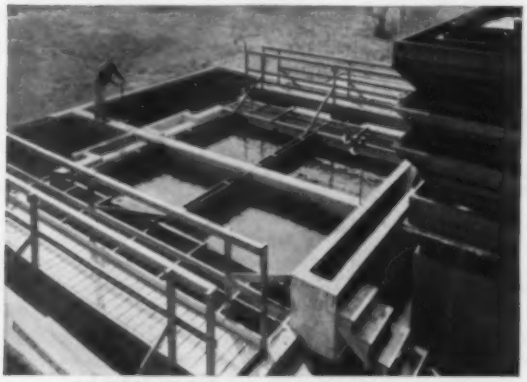
Item	Operation With: Hydrated Lime	Operation With: Pulverized Quicklime
Period of test	June 1952	June 1954
Total water production, mg	90.785	90.456
Chemicals used, lb per mg:		
Lime	1,715	1,305
Alum	.....	14.3
Sodium silicate	67	.....
Sulfuric acid	7.75	.....
Cost of lime, $ per ton	24.65	27.88
Cost of lime, $ per mg water	21.10	18.20
Chemical analysis of lime:		
Calcium oxide (CaO), %	73[a]	97.2
Calcium hydroxide ($Ca(OH)_2$), %	97.77	.....
Magnesium oxide (MgO), %	0.52	0.92
Aluminum oxide (Al_2O_3), %	.....	0.25
Silica (SiO_2), %	0.06	0.64
Iron oxide (Fe_2O_3), %	0.32	0.09
Calcium carbonate ($CaCO_3$), %	.....	1.39
Moisture and CO_2, %	0.33	.....
Sieve analysis:		
Passing 20—mesh screen, %	.....	100
Passing 50—mesh screen, %	.....	95
Passing 100—mesh screen, %	.....	90

Partial analysis of water: Item	Raw Water After Aeration: Plant 1	Plant 2	Mixture	Treated Tap Water[b]
Alkalinity, phenolphthalein[c]	0.0	0.0	0.0	10.0
Alkalinity, methyl orange[c]	185	207	200	20.0
Total hardness	252	252	252	80.0
Chloride, as ppm Cl^-	120	52	81	.....
pH	7.2	7.2	7.2	9.4

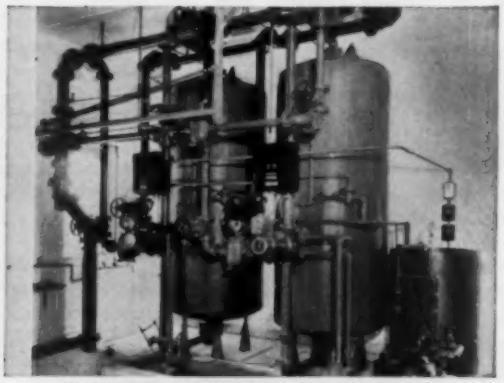
[a] Calculated
[b] Mixture of 1 and 2
[c] As ppm $CaCO_3$

TURBIDITY gets cut from 1500 to less than 5 ppm in this Precipitator. Mt. Carmel, Ill. Cons. Eng.: *Warren & Van Praag, Inc.*

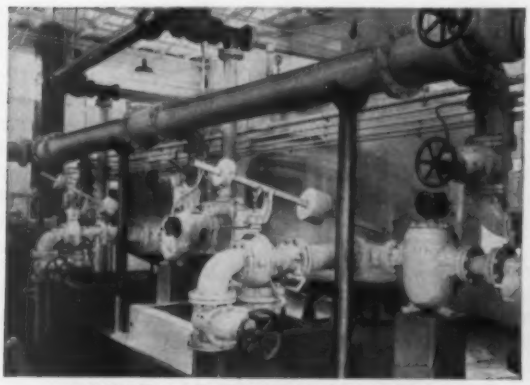
SEA WATER saves $32,980 per year over salt for regenerating Softeners. Hollywood, Fla. Cons. Eng.: *Reynolds, Smith & Hills.*



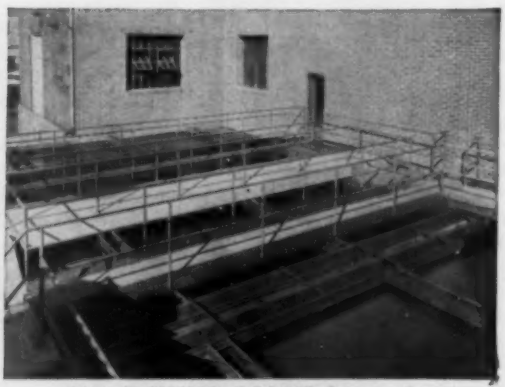
30 PPM IRON gets cut to 0.14 ppm in Aerator and Precipitator . . . even before filtration! Fairless Hills, Pa. Cons. Eng.: *H. H. Le Van, Jr.*



269 PPM HARDNESS is removed by these automatic Softeners. Aerator and Filters cut iron. Martinsville, Ill. Supt.: *O. Wiser.*



AUTOMATIC CONTROLS backwash, regenerate, rinse and return Softeners to service. New Smyrna Beach, Fla. Cons. Eng.: *Russell & Axon.*



OLD SETTLING BASINS house these modern Precipitators that boost capacity. North Kansas City, Mo. Cons. Eng.: *C. A. Haskins.*

HARDNESS TESTER (left) initiates regeneration by Automatic Controls (right). This new Permutit plant, with Q resin, softens 72% more water—using same manpower, less salt! E. Aurora, N. Y. Village Eng.: *E. J. Maurer.*

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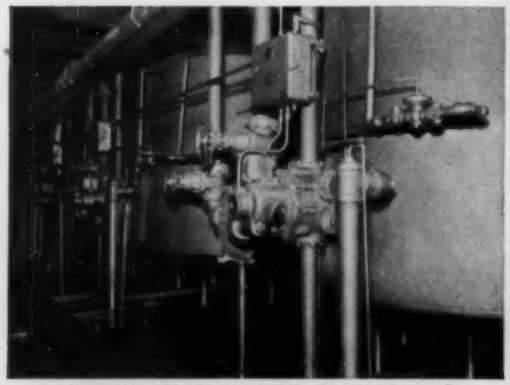


SOFTENER CAPACITY TRIPLED and $7,000 yearly saved on salt by change from zeolite to Permutit Q. Normal, Ill. Cons. Eng.: *Farnsworth & Conley.*

TRIPLE TROUBLE! 275 ppm hardness, 200 ppm alkalinity, 3 ppm iron are reduced by this Precipitator. Staples, Minnesota. Supt.: *E. H. Klang.*

Water Without Minerals

by I. B. DICK

Asst. Chief Chem. Engr., Consolidated Edison Co., New York

IN WHAT is believed to be the largest plant of its type ever built, demineralizing of 2,500,000 pounds of water an hour was the unusual problem successfully solved by power engineers in one of New York City's major steam-electric generating stations.

Steam and electric power for most of the buildings in the city's midtown skyscraper district is supplied by the Waterside station of Consolidated Edison. The recently modernized plant—right next door to the big United Nation's Secretariat building—has a capacity of 658,200 kw and 6,460,000 pounds of steam per hour (at 1400 to 1710 psi and 950°F.)

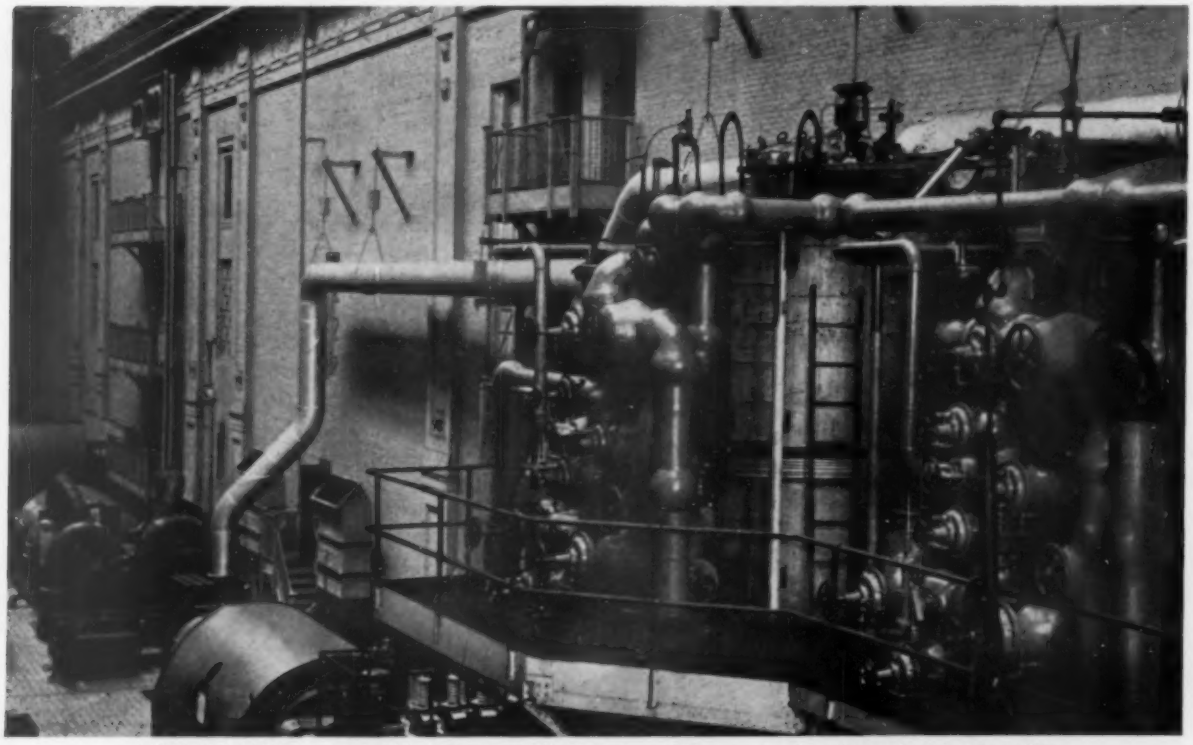
All steam passes through six topping turbines discharging at 200 psi. As much as 1,800,000 pounds per hour of this steam feeds into the skyscraper heating systems. This process steam is not returned and must be replaced by makeup water. Blowdown, soot blowing and incidental losses increase the amount of makeup water needed so that Waterside station's total requirements equal nearly 2,500,000 pounds per hour. This raw water comes from New York City's Croton and Catskill reservoirs, which have silica contents of 6.3 and 2.4 ppm, respectively.

Silica concentration, which in the past was around 30 to 35 ppm in the boilers, fouls the condensing turbines, requiring caustic washing of each every 4 to 6 weeks. This silica fouling increased generating costs through decreased turbine efficiencies and capacities; increased outage time and increased boiler blowdown, which wasted valuable heat, water and chemicals. With the zeolite softening equipment formerly used to treat makeup water, 6 per cent boiler blowdown was required to maintain the dissolved solids content of the boiler water at less than 200 ppm.

Preliminary studies revealed that the savings in operating costs realized by demineralizing the water justified a considerable capital investment for water treating equipment. This held true even though some savings in operating costs from silica-free water would be partly cancelled by the increased treatment costs of the makeup water.

Added to the problem of removing silica from 2,500,000 pounds of water per hour was the need to cope with a space problem. To keep pace with New York's expanding demand for power, the Waterside station has undergone many modernization programs. These programs have been so extensive that little remains of the original station except the shell—and even that has had its roof raised. Hence, space is at a premium and was a decisive factor in the selection of mixed-bed demineralization equipment.

Studies by Consolidated Edison's chemical engineers proved that evap-



THE WORLD'S largest mixed-bed demineralizing plant conditions water for steam-electric generation.

oration of the makeup water would be impractical and that ion exchange methods offered the only hope of solution. Pilot plant studies revealed that strong-base anion resins, when intimately mixed with cation resins, would remove silica to extremely low residuals. The studies also indicated that the two-bed demineralizers would also remove silica, but required more space, which was not available.

The solution to the problems was found in the use of the mixed-bed or monobed demineralized*. Six 11-foot diameter mixed-bed units, each rated at 1,000 gpm, with automatic controls and necessary pumps, tanks and piping, were installed on steel platforms under the roof and in a corner of the turbine room.

The first four units were started up in August 1954; the complete plant went into operation two months later. Because no data were available on the performance of mixed-bed demineralizers on New York City water, a small pilot unit was operated for a year and a half prior to starting the first units of the full-scale plant.

Results of Pilot Studies

Experience gained from the mixed-bed pilot plant studies resulted in a change of one of the resins, the development of a photoelectric colorimeter, and a change in regeneration procedure. During these tests, it was discovered that conductivity does not always break before silica; therefore, silica tests are necessary to determine bed exhaustion.

To permit rapid removl of an exhausted unit from service, it was decided that silica tests should be run by the operators at the plant site instead of by chemists in the laboratory. Unfortunately, commercially available colorimeters with the required sensitivity were unsuited for use outside the laboratory, but the staff successfully developed its own rugged colorimeter, which measures silica content down to 0.01 ppm. The studies also proved that when demineralization capacity is lost, presumably due to organic fouling, it can be restored by continuing caustic injection and rinse cycles of regeneration until the rinse is free of chlorides.

The plant design, amended by the results of the pilot plant studies, was proven to be amazingly satisfactory. It was so easily put into service that Consolidated Edison engineers continually expected major troubles to develop. They never did. Moreover, the plant has consistently produced water with a silica content less than 0.02 ppm and a conductivity averaging a little better than one micromho.

The water first passes through four hydrogen zeolite softeners operated in series. These softeners were part of the old split-stream zeolite softening plant installed in 1940 as the largest carbonaceous zeolite softening plant in the world. They were retained to permit the removal of bicarbonates by degasification rather than anion exchange, to filter raw water, and to remove calcium—thereby preventing calcium sulfate fouling of the mixed-bed units.

From the softeners, the water is pumped through two decarbonators and then flows by gravity to rubber-lined wet wells. From wet wells the water is pumped through the mixed-bed units to a bituminous coated storage tank. The mixed-beds are operated in parallel at full capacity, with units pulled in or out of service according to makeup requirements. Unlike cation softeners, these units can be taken out of service and then returned to service without any impairment of water quality.

Centralized Controls

Supervision of the entire triple-decker plant is centered in one small nook which includes the instrument panelboard, sampling table, and colorimeter for silica determinations. Regeneration of the beds may be done in any one of three ways:

1. Automatically with manual initiation.

2. Semi-automatically through remote manual pushbuttons on the panelboard.

3. Manually by means of handwheels at the valves.

By the first method, the operator, upon checking silica or being warned by the conductivity recorder, merely presses a pushbutton to initiate the regeneration cycle. At the completion of the cycle the unit is returned to service or held in standby, depending on the setting of a selector switch.

The second, or semi-automatic, method permits the operator to stay at the panel but still open and close valves, start and stop pumps, and regenerate the beds manually by pushing buttons on the panel. The hydrogen zeolite softeners are not provided with automatic controls; hence, the instrument panel is located near them to permit one operator to supervise the entire plant. Without automatic controls, probably three operators would be needed per shift due to the three-level layout.

The third, or manual, procedure is more of an emergency method. When any of the equipment must be taken out of service, the necessary valves can be closed or opened manually and there will be no chance of accidentally opening a valve from the panelboard.

Instrumentation

Because of close quarters the instrument panelboard is greatly condensed. Across the top of the panel are six flow recorders with Minneapolis-Honeywell electronic integrators. These are electrically connected to meter bodies measuring the flow of softened water to each of the six mixed beds. Lights below each of the flow meters indicate when a bed is exhausted, when it is under automatic control, and whether it is on standby or in service.

METER bodies electrically connected to control panel.

*Developed and manufactured by Illinois Water Treatment Co.

CENTRALIZED instrument panel handy to the sample table.

An ElectroniK potentiometer records and indicates the pH of the treated water. It is equipped with an alarm switch, which actuates a red light to warn of low pH. All the alarm lights are in the middle of the panel.

A strip chart recorder below the signal lights and pushbuttons alternately records the conductivity of the effluent from each of the six beds. Two alarm switches sound a horn and light a signal under the flow recorder for a mixed bed when the bed nears exhaustion. The conductivity end point is then supplemented by silica determinations.

Other instruments record and control the flow of regenerants and rinse water. A temperature controller under No. 5 flow recorder pneumatically positions a steam valve on the caustic regenerant line. It was found necessary to heat the caustic solution for greatest efficiency, and this is done by steam injection. A non-indicating on-off temperature controller mounted behind the panel serves as a high temperature cut-off and actuates a second valve to shut off the steam at the excessive temperatures that would result from failure of the first system. This high-limit safety control insures the ion exchange resins against damage from overheating.

A ratio flow controller measures the flow of water and controls the flow of 50 per cent caustic solution to maintain the predetermined concentration to the mixed bed. The steps of the regeneration cycle are indicated by lights below the red alarm lights. They include the following:

1. Start regeneration
2. Drain
3. Backwash
4. Settle
5. Regenerate
6. Drain
7. Agitate with air
8. Fill and vent air
9. Settle
10. Rinse

After regeneration is completed, a unit is either automatically returned to service or held in standby.

Regeneration Cycle

Regeneration takes about four hours and consumes about one per cent of the treated water produced on a run. While the quantities of regenerant chemicals are presently excessive, they will eventually be reduced as much as 30 per cent. Currently the costs of regeneration are about $7.00 per 1,000,000 pounds of water or $0.0583 per 1,000 gallons. The Illco-Way design permits both acid and caustic regeneration simultaneously. This is a big factor in saving time.

If the regeneration steps are started manually from the board instead of automatically, they must be taken in sequence; pressing the button for any particular step automatically cancels the preceding steps. Also, no more than one bed can be regenerated at a time. A non-indicating conductivity measuring device determines the end point of regeneration.

Water for regeneration is required at three different rates. This is achieved by means of a single controller in a unique hook-up. One flow recorder is equipped with a Fixed Indexet mechanism by which it is possible to change the control index setting of the recorder by changing the air pressure on the bellows. The 150 per cent proportional band control unit, also included in the instrument, positions a diaphragm motor valve controlling the flow of dilution water to both the acid and caustic regenerant systems. Three parallel air lines are connected to the Indexet mechanism. Each is equipped with a pressure regulator followed by a three-way motorized valve.

Each valve either bleeds air to the atmosphere or applies the air pressure in its line to the mechanism. The three regulators are set to obtain the desired pressures on the Indexet unit, which in turn sets the desired set point on the flow controller. Each valve is energized in turn to sequence the three flow rates. The fastest rate is used for backwashing. A rate at about one-half that for backwashing is used for injection of the regenerants. This rate is applied to the caustic feeding system and measured by the caustic recorder, which in turn regulates the rate of 50 per cent caustic feed.

Acid feeding rates are obtained differently. Dilute acid is pumped to the bed from a tank at a constant rate. Meanwhile, concentrated acid is pumped to the tank—first slowly, then at a faster rate. Dilution water is taken from the line carrying hydrogen zeolite treated water by a float-actuated level control valve. This system obtains the desired results with the minimum of equipment. It represents excellent and clever engineering design, since flow rates and material balances were quite complicated to establish.

The third rate of flow of water for the regenerating cycle is a very slow rate applied for a brief period to vent the bed of air after the mixing step.

Results Are Gratifying

Since the demineralizers have been installed, the silica content of make-up water has been reduced from 1 to 2 ppm to 0.01 ppm and the silica content of the boiler water is being correspondingly reduced. Since the steam condensate system has been high in silica since 1938, it is taking time to eliminate the silica that has accumulated over the intervening years. Nevertheless, it has been possible to reduce continuous blowdown substantially. In addition, since turbine fouling has diminished, cleaning schedules have been lengthened and the situation continues to improve.

Iron and Manganese Removal

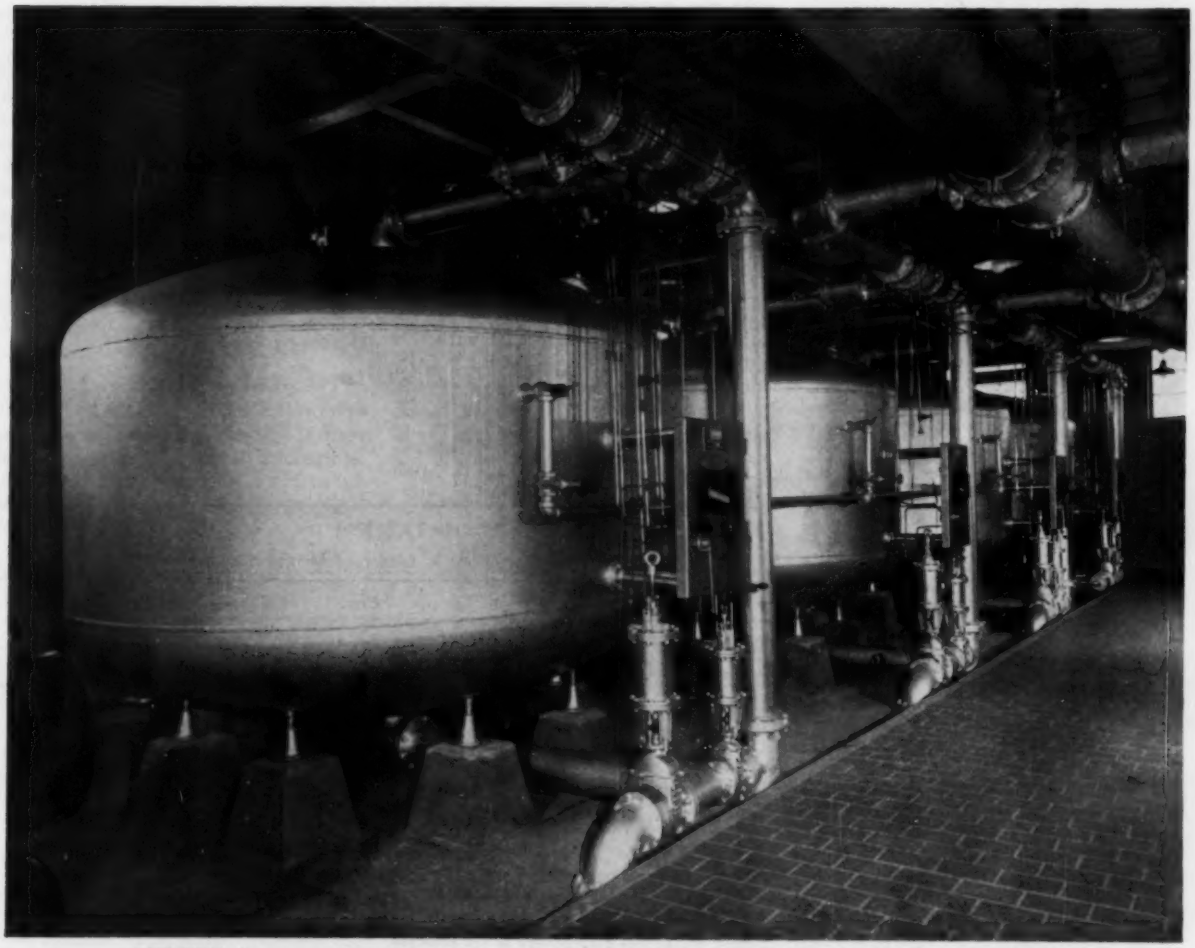
by S. B. APPLEBAUM

Director, Water Treatment Division, Cochrane Corp., Philadelphia, Pa.

THE TECHNICAL LITERATURE on water treatment contains many articles on iron and manganese removal. The subject is about 100 years old. Yet despite its antiquity there has been evidence, even of late, of differences of opinion when those skilled in the art are confronted with a specific iron and manganese removal problem. It is, therefore, the purpose of this paper mainly to explore these differences and to show how they may be resolved by pilot plant testing, using as an example the case of a large iron and manganese removal plant at Jamaica, N.Y.

Well waters are often preferred to surface supplies because of their greater clarity and lower temperatures. However, when the well water contains more than about 0.2 to 0.3 ppm of iron plus manganese, these impurities come out of solution in the

*Presented at the Annual Water Conference, Engineers Society of Western Pennsylvania, Pittsburgh, Pa.



ONE SIDE of pressure filter installation for iron and manganese removal at Jamaica Water Supply Co.

form of brownish to purple colored precipitates, which cause many troubles to industrial and household users.

These troubles may be briefly summarized as follows:

1. An astringent metallic taste is imparted to the water.

2. In industry, discoloration of paper, textiles, ice, leather and all the other wet processed manufactured products takes place.

3. In the household, stains form on porcelain basins, bathtubs, glassware and dishes, as well as the laundry wash.

4. For cooling water, not only do the precipitates clog piping, but the iron stimulates the growth of certain plankton such as *Crenothrix*, which form slimly stringy deposits in the cooling towers, piping and heat exchangers.

5. Today, in the rapidly growing field of demineralization for high-pressure boiler plants, iron and manganese foul the ion exchange resin, so that their removal in pretreatment plants is essential to protect the high investments in these plants.

Chemistry of Treatment

In general, there are two main forms of treatment, as follows:

1. Those involving oxidation reactions:
   (a) Aeration, with or without settling and finally followed by sand filtration.
   (b) Filtration through manganese zeolite.
2. Ion exchange without oxidation, combining water softening with the iron removal.

The chemical reactions are given in Table 1.

In the usual oxidation reaction accomplished by aeration (in the case of iron as given in Eq. 1), the ferrous bicarbonate, which is the prevailing form present in well water, is oxidized by the oxygen added to form ferric hydroxide precipitate and free carbon dioxide is liberated.

In the case of the manganese zeolite, which, in fact, was developed about 50 years ago[1] in Germany to cope with high manganese rather than iron, it is produced in the following manner:

Sodium zeolite is first treated with manganous chloride or sulfate to convert it to manganous zeolite (see Eq. 2). Then it is treated with potassium permanganate to form manganic oxides in the zeolite (see Eq. 3). These higher oxides give up oxygen gradually as required to oxidize the manganese in the water which is filtered out by the zeolite bed (see Eq. 4). Periodically the bed must be reoxidized or regenerated by permanganate or other oxidizing reagents to restore the higher active manganic oxides. These regenerations are obviously expensive.

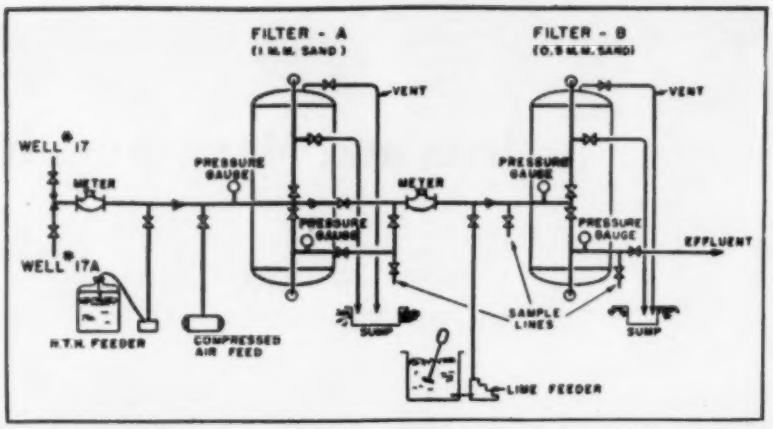


Fig. 1—PILOT PLANT flow diagram, showing connections of chemical feeders and controls.

If the water contains much more iron than manganese it is desirable as well as economical to remove the iron first by aeration and sand filtration, leaving the more difficult manganese removal to be accomplished by the manganese zeolite. This is not only true for manganese zeolite, but Wieters[2] also recommended it as well for sand filter plants.

The non-oxidizing ion exchange reactions merely involve exchanging ferrous iron and manganous manganese in the water for the sodium of sodium zeolite simultaneous with the usual water softening (see Eq. 5). In fact, the iron and manganese continue to be removed even after the hardness begins to break through. This process has been used successfully for fairly soft waters, even containing over 50 ppm of iron.

The only precaution necessary is that no dissolved oxygen enters the water before the zeolite bed. Even if some dissolved oxygen is sucked in at the suction of the well pump, it causes ferric hydroxide precipitates to foul the zeolite and this stops the ion exchange reactions.

This method has found application in many municipal and industrial plants when water softening is desired at the same time as iron removal. However, where iron and manganese removal alone without softening is desired (as was the case at Jamaica, N.Y.) only the oxidation methods are considered.

Factors Influencing the Oxidation Reaction

The speed of the oxidation reaction determines the complexity and, therefore, the first cost of the iron removal equipment required in any given case.

TABLE 1

Chemical Reactions in Iron and Manganese Removal

Reaction	Equation	Eq. No.
Oxidation*	$4\,Fe(HCO_3) + O_2 + 2H_2O \rightarrow 4\,Fe(OH)_3 + 8CO_2$	1
Preparation of manganese zeolite	$Na_2O.Z + MnCl_2 \rightarrow MnO.Z + 2NaCl$	2
	$MnO.Z + 2KMnO_4 \rightarrow K_2O.Z \cdot MnO.Mn_2O_7$	3
With manganese zeolite†	$K_2O.Z \cdot MnO.Mn_2O_7 + 2Mn(HCO_3)_2 \rightarrow K_2O.Z \cdot 5MnO_2 + 4CO_2 + 2H_2O$	4
Ion exchange without oxidation	$Na_2Z + \begin{matrix}(Ca)\\(Mg)\\(Fe)\\(Mn)\end{matrix} \cdot (HCO_3)_2 \rightarrow \begin{matrix}(Ca)\\(Mg)\\(Fe)\\(Mn)\end{matrix} Z + 2NaHCO_3$	

*Using ferrous bicarbonate as the example.
†Using manganese bicarbonate as the example.

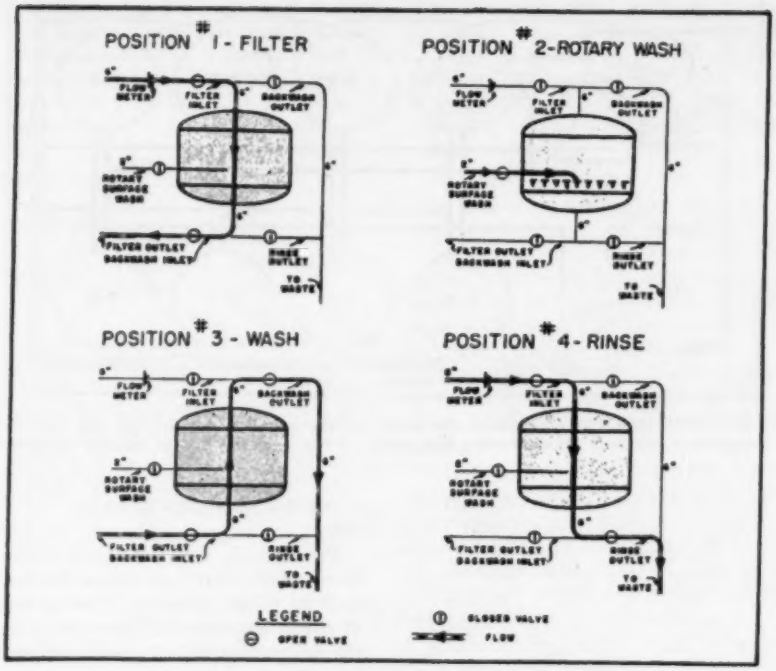


Fig. 2—OPERATING CYCLE of wash, rinse and filter

This speed is influenced by a number of factors which should be briefly discussed, as follows:

1. Well waters containing high alkalinity and high total dissolved solids are rapidly oxidized. Such waters, as in the case of Mid-Western wells, when freshly drawn from the well pump show rapid formation of first a milkiness and then soon thereafter the usual yellow to brown iron hydroxide precipitates. However, along the Eastern seaboard wells are, as a rule, lower in alkalinity and total solids and the oxidation reaction is much slower.

2. pH value is important. Iron hydroxide precipitates are most rapidly and completely formed at a pH range of 7.0 to 9.0. Manganese, on the other hand, calls for a higher optimum pH of 8.5 to 10.0. Therefore, if the well water has too low a pH value the addition of lime or soda ash is required.

If the well water contains high free CO_2 which depresses the pH value, the use of atmospheric open aerators or closed forced draft aerators is indicated to remove some of this CO_2 first to save some of the alkali later added.

3. Organic matter present, as in the case of well waters in swampy regions, inhibits and slows down the oxidation reactions. Such organic matter must then be removed by prechlorination.

Contact Filters or Solids Contact Reactors Preceding Final Filters

Where inhibiting factors are present or when the amount of iron and manganese present is relatively high, the use of single filtration alone would result in high pressure losses and too frequent backwashing. In such cases the use of contact filters or solids contact reactors is indicated. These remove part of the iron and then the final filters finish the removal.

Contact filters employ coarser filter particles than the final filters. There is, therefore, more space between the particles for the storage of precipitates without causing such rapid build-up of pressure losses. Also, the precipitates in the contact filters act as catalytic agents to speed up the oxidation of the iron and manganese.

Various materials are employed in the contact filter beds such as pyrolusite[3], coke, lava[4], calcite, and (mainly) gravel or coarse sand.

Settling basins, or preferably solids contact reactors, are justified if the amounts of iron and manganese are so high that even the contact filters would be overloaded and cause too high a head loss and too frequent backwashing.

Moore, at Harvard University, made some research studies[5] with a solids-contact laboratory unit proving the efficacy of synthetically prepared sludge for this purpose.

However, contact filters have two advantages over settling tanks as follows:

1. Lower initial cost.

2. Contact filters can be made in the form of pressure units so that repumping is avoided.

With this brief review of the factors influencing the design of iron and manganese removal plants in general, we may now proceed to a discussion of the Jamaica case.

Jamaica, Long Island

As Hobson and Ley pointed out in 1950[6], the Jamaica Water Supply Company draws its supply from a number of wells then delivering about 67 mgd.

These wells were not all located at one spot, but were dispersed to obtain maximum yield as well as to facilitate their most economical connection to the distribution system.

The well waters proved an economical and suitable water supply in most respects. The hardness was not excessive, so that water softening was not compulsory for this municipal application. However, iron and manganese were present in excessive amounts in some of the wells, causing complaints by the consumers. Therefore, a number of water treatment plants were found necessary. In the past different types of equipment were

TABLE 2

Summary of Bids on Iron and Manganese Removal at Jamaica, N. Y.

Bidder	Type of Equipment	Bid,* $
A	Manganese zeolite pressure filters (4.5 gpm per sq ft rate), also lime feed (20 psi loss of head)	78,700
B	Double-deck lava and sand filters (4.5 gpm per sq ft rate), also soda ash feed, compressors for 134 cfm	139,000
C	Open aerator, gravity filters, lime feed, and high-service pumps ($6,000). To this must be added the estimated value of concrete containers ($50,000)	111,000
D	Single pressure filtration (5 gpm per sq ft rate)	46,800
D_1	Single pressure filtration (4 gpm per sq ft rate)	65,650

*1949 bid; increased by 10 per cent escalator (where necessary) to put all bids on the same firm basis.

installed at two of the stations:

1. At Station 6, a 5-mgd plant consisted of a gravity plant with open atmospheric aeration, chlorination, settling and filtration through gravity filters containing a 27-inch deep sand bed. This involved a secondary high-lift pumping station after the water treatment plant.

2. At Station 18, a 2-mgd plant consisted of a pressure plant without repumping, but the individual filters were combination units containing a contact roughing filter of coarse lava in an upper deck and a final finishing filter containing a mixture of sand and calcite in the lower deck. This plant was described by Ley in a previous article[4]. Compressed air was distributed continuously through a perforated pipe system inside each unit just below the lava contact filter deck, bubbling up through it counterflow to the water.

The new project, for which this third iron and manganese removal plant was to be built had four wells some distance apart. However, instead of building separate plants at each well it was decided to install a central plant of 5-mgd capacity to treat the combined output of the wells.

The combined raw water was clear and colorless, but had the following average chemical analysis:

Constituent	*Conc., ppm*
Total hardness (as $CaCO_3$)	118
M.O. alkalinity (as $CaCO_3$)	82
Free CO_2 (as CO_2)	18
Chloride (as Cl)	11.8
Iron (as Fe)	0.64
Manganese (as Mn)	0.22

A specification was written inviting bids on iron and manganese removal equipment for 5-mgd capacity to reduce the sum of the Fe and Mn from 0.86 ppm to under 0.2 ppm. Preference was expressed for pressure units to avoid repumping, and losing not only 10 psi pressure with only one backwashing daily, but alternate proposals were allowed if other types were justified.

When this specification was received the author's company felt that single filtration would suffice. However, it was decided that it might be advisable to investigate and prove that the desired results could be obtained by such a simple type of single filtration preceded by pressure aeration, injecting small quantities of chlorine and compressed air directly to the common inlet together with injection of lime under pressure if pH adjustment was needed. Such an investigation seemed all the more necessary in this case because of the fact that previous designers had apparently found that the more elaborate types of treating equipment described had been justified for other wells in Jamaica.

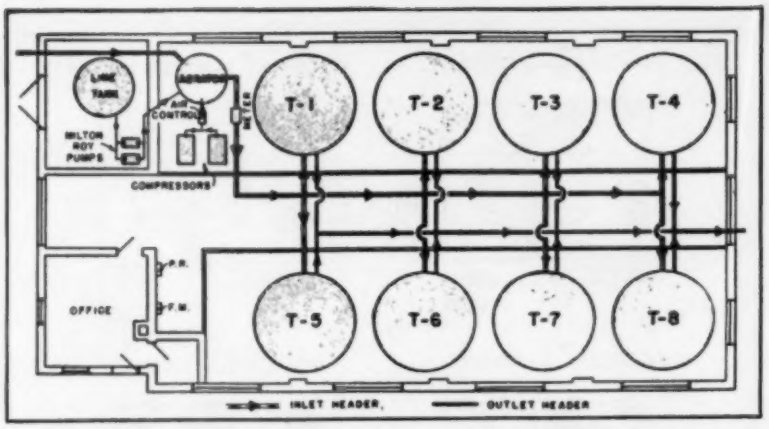


Fig. 3—NORMAL FLOW through the eight pressure filters comprising the iron and manganese removal plant serving five wells of the Jamaica Water Supply Company

Therefore, it was decided to install a pilot plant at the site consisting of two 12-inch diameter pressure filters to act in series, one with 1.0-mm effective size coarse sand to act as a roughing contact filter and the other with 0.5-mm finer sand to act as a final filter. In addition, a hypochlorite feeder to inject Cl, a lime feed, and an air compressor and receiver were included. Thus there was available all the equipment needed to answer the following questions:

1. Is contact filtration ahead of final filtration necessary, as was previously installed at Station 18?

2. If single filtration suffices what rates of flow in gpm per sq ft of filter area would give the desired results with no more than 10 psi loss of pressure in 24 hours?

3. Is chlorine addition, plus lime addition for increase in pH value, necessary for iron and particularly manganese removal, and if so what pH values are optimum?

Fig. 1 shows the pilot plant set-up. The results obtained may be summarized as follows:

1. Single filtration through a 15-inch depth of 0.5-mm sand at a rate of 5 gpm per sq ft gave the desired results and within the desired loss-of-head limit.

2. Prechlorination was helpful but not essential.

3. Injection of air was necessary if prechlorination was not used.

4. Addition of lime and increase of pH above 7.1 was not needed for reduction of iron to less than 0.03 ppm, but increase of pH value to about 8.3 was required for reduction of manganese to figures as low as 0.02 ppm.

When bids were received it was found that there were four bidders, each of which bid on a different type of treatment plant. These bids, for the equipment not erected, are summarized in Table 2.

The award was made to Cochrane Corporation on bid D_1. The decision to use the 4-gpm per sq ft rate was based on the desire to have a greater factor of safety in avoiding excessive pressure losses.

The plant finally installed consisted of the following units:

1. 8 pressure filters, 12 ft in diameter by 5 ft high with 15-inch depth of 0.55-mm (effective size) sand resting on several layers of different sizes of gravel of 20-inch total depth.

2. Rotary surface washers.

3. Lime tank 9 ft in diameter by 5 ft high and two volumetric reciprocating pumps for lime injection.

4. A pressure aerator 5 ft in diameter by 6 ft high with two air compressor and receiver sets. This was enough for injection of the small amount of air (24 cfm each) into the common inlet to oxidize the iron and manganese. Controls consisted of Fischer & Porter Flowrator and Moore differential flow controller.

5. Filter valves consisting of hydraulic cylinder-operated gate valves controlled manually by a pilot disc valve on each unit, which had the four operating positions marked on it. The operator turns this pilot valve by a small hand lever to the four positions, one after the other, and the pilot valve opens and closes the correct large gate valves in the right order automatically. Fig. 2 shows these four positions.

6. Individual unit Bailey rate-of-flow meters with flow nozzles, pres-

sure gauges and a backwash rate of flow meter. These constituted the instrumentation. Fig. 3 shows a plan of the entire plant. The photo shows a battery of four filters on one side of the aisle.

Results Since 1950

The plant was started in January 1950. In the period from then until August 30, 1955, the following operating results were obtained[7]:

1. 8,925 mg of water were treated.

2. Another well was added and the plant is now operating at a 3,200-gpm average and 4,500-gpm maximum. The latter is 6.5 mgd, or a rate of 5.0 gpm per sq ft instead of the initial rate of 4 gpm per sq ft based on 5.2 mgd (3,600 gpm).

3. The usual treatment consists of adding about 10.5 ppm of lime to maintain a pH of 7.5.

4. The iron and manganese in the combined raw water varies with the wells used. The following gives the maximum in the incoming influent and the usual iron and manganese in the effluent. Some of the five wells have over 1 ppm present, but they are diluted to about one half this value by the other wells.

	Combined Raw Water	*Effluent*
Iron, ppm as Fe	0.74	0.02
Manganese, ppm as Mn	0.23	0.03
Total	0.97	0.05

5. Backwashing is required about once in 32 hours for each unit and the loss of head at the end of the run is about the same as in 1950, when the plant started, or 7 psi.

6. Air is added continuously.

7. Chlorine is added continuously into only one of the five wells to oxidize some odorous organic matter present. Then a little ammonium chloride (5 lb per day) is mixed and added with the lime. Therefore, only a chloramine residual of about 0.2 ppm is present in the combined filter influent.

8. There has been no loss of sand.

9. The pilot disc valves have been re-ground occasionally.

10. Some fine sand from one of the wells collected in one of the units nearest to the common inlet. This caused the filter bed to grow so that the rotary surface wash stopped. The loss of head through this unit also increased. The fine sand was then scraped off and the unit returned to normal.

11. The backwash procedure consists of (a) rotary surface wash for 1 minute, (b) backwash at 1,500 gpm for 10 minutes, and (c) filter to waste at 500 gpm for 5 minutes. The total waste water amounts to about 2.5 per cent of the total water treated.

12. The total erected cost was $170,700, or $34,138 per mg, including structure, electrical, plumbing and heating, foundations, labor of erecting equipment, and connection of piping to the distribution system. The operating cost is:

Electrical energy for pumping from ground to service	$24.67
Treatment	2.19
Operating labor	4.28
Total, per million gallons	$31.14

Conclusions

This case history indicates that even today there is considerable difference of opinion when experienced bidders are invited to bid on equipment to solve a specific iron and manganese removal problem.

In fact, the differences of opinion in this case resulted in a range of first cost for equipment alone from $50,000 to $139,000.

The erected costs would be still farther apart because the more complicated types of equipment, such as the gravity filters, etc., would cost more to erect. Therefore, it is conservative to estimate that the saving to the user in this case amounted to more than $100,000 in total investment, as well as an appreciable saving in operating cost, by adopting the design installed.

In passing, it is of interest to report that in Station 18, where the double-deck contact lava beds over the final sand calcite beds were originally used, it was found possible to remove the lava from the upper decks without affecting the results. Such contact filters are no doubt valuable for high iron bearing waters, especially with high organic inhibitants present. Nevertheless, at Station 18, with the present well water, and at this later plant previously described, contact filtration or sedimentation preceding the single filtration was not required.

The pilot plant tests were very valuable in determining the allowable rates per square foot, which determined in great part the required investment. There is no substitute for such pilot plant testing, not only in iron removal problems but also in many of the related water treatment fields.

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Compressed Air in Water Works

by EDMOND C. POWERS

Educational Director, Compressed Air and Gas Institute, Cleveland, Ohio

THE APPLICATIONS of compressed air in water pumping stations and treatment plants until recently have been limited. Although not completely incongruous in the average water works, compressors nevertheless have occupied a relatively minor position among the pumping stations[1] components.

With the exception of maintenance functions and those water works using air lift pumps, the need for compressed air was confined to pipe testing, caulking operations, and minor control systems that required one or two small capacity, light duty compressors of perhaps 0.5-horsepower each.

Now, however, the ever-increasing recognition of compressed air as a safe, simple, and dependable mode of power has caused its application to spread throughout the entire pumping station, enveloping control devices of all types, aerating systems, soot blowing, and a host of other associated water works activities. A few of these applications are briefly reviewed here to show what compressed air can do better and cheaper for the water works operator.

Air Lift Pumping

If air lift pumping is not the oldest compressed air application in the water works, it certainly must be close to the oldest such application. Successfully used for many years in a number of stations, this unit is by no means obsolete. It still finds wide acceptance in deepwell areas where long-shafted vertical turbine and submersible wet pit pumps are impractical or uneconomical.

Its chief advantages are that it has no submerged wearing parts to be affected by abrasives suspended in the water, and crooked well shafts do not materially affect its operation. Water contamination by the pumping medium is practically nil, thereby reducing the filtration and purification requirements to a slight degree.

Furthermore, because the power source is centralized and may consist of a single compressor and motor to handle a group of wells, installation costs are lower. On the other hand, to provide an individual mechanical pump and motor for each well of a field sometimes results in numerous substations a considerable distance from each other. With air lift pumps and a centralized power source, accessibility and maintenance problems are simplified.

Aeration Uses

Where aeration figures prominently in conditioning the water, compressed air offers real possibilities.

Two of the more important considerations in efficient aeration are (a) the amount of air-water surface, and (b) the duration of the air-water contact time. Since air at a given pressure can be made to pass through smaller pipe openings than water at the same pressure, the air can be broken up into countless small bubbles that will present a maximum air-water surface ratio. Of additional importance is the fact that an air bubble will require a longer time to reach the liquid surface than will a sprayed water droplet to fall back to the water. The contact time between the water and air, therefore, is increased substantially, providing better aeration. The obvious advantages of control pressure variation in such a system immediately open up new possibilities in aeration control.

$$T = \frac{V (P_1 - P_2)}{C P_o}$$

- T = Time receiver will supply air from upper to lower pressure limits, in minutes.
- V = Volume of receiver, in cubic feet.
- P_o = Atmospheric pressure, in pounds per square inch absolute.
- P_1 = Maximum tank pressure (compressor discharge pressure), in pounds per square inch absolute.
- P_2 = Minimum tank pressure (pressure required to operate tool), in pounds per square inch absolute.
- C = Air required (from study of load cycle), in cubic feet per minute.

Fig. 1—PROTECTION provided by compressed air system in event of power outage

It is conceded that the greater the air pressure, the greater will be the volume of air flow. But greater air flow also means increased aeration taking place. If, then, instruments could be used to periodically measure the condition of the water, automatic control of aeration could be achieved. On dictation by the instrument measuring the condition of the water, the volume of air for aeration could be varied to meet the immediate requirements of the water conditioning system.

In many instances severely cold weather will influence spray-type aeration systems to such an extent that the use of compressed air is an absolute necessity if aeration is to retain its efficiency. Seasonal and perhaps daily changes in aeration requirements are easily handled with compressed air.

Filter Cleaning

Filter beds, too, can be reactivated faster by means of air under pressure. Speed of reactivation is a vital factor in the warm months when water consumption is at its peak and the shutdown time of a filter bed for cleaning must be at a minimum.

Low-pressure air for agitation of the sand will reduce backwash time considerably. The same air system that is used for maintenance can be used here also. It only becomes necessary to install pressure regulating valves immediately before the air distribution pipes in the filter beds. A reduction of the air pressure to about

10 pounds per square inch is adequate in most plants.

With a cleaning pressure of 10 pounds per square inch, and a plant air system with a pressure of 100 pounds per square inch, only a small air receiver is required to store sufficient air for a cleaning cycle. For instance, a 90 cubic foot receiver holding air at 100 pounds per square inch would supply approximately 420 cubic feet of air at 10 pounds per square inch.

This ability of the compressed air system to store up power by means of air receivers is one of its most outstanding features. Extra large storage tanks can provide air to operate controls, valves, and other vital components for minutes after a power failure has shut down the electric system. The equation in Fig. 1 can be used to check the plant system to see how well it protects against emergencies.

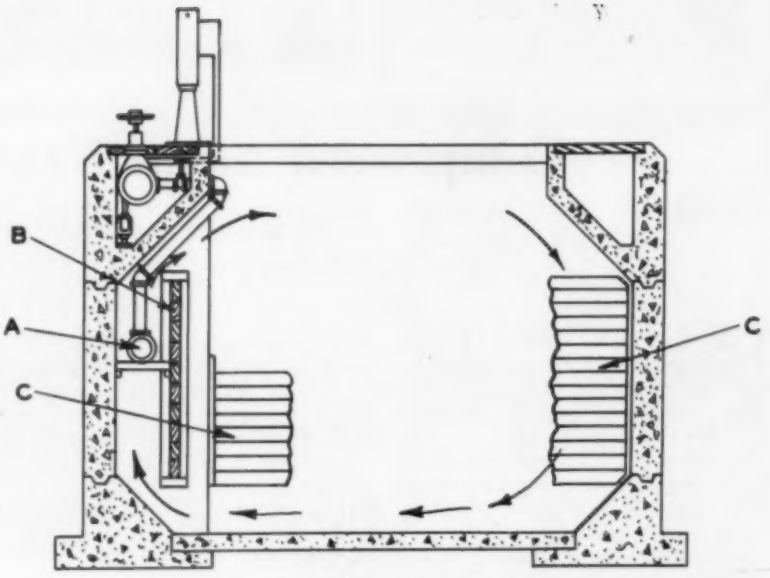

Fig. 2—AERATOR-FLOCCULATOR operated by compressed air

Flocculation

Most flocculation processes require rapid mixing at the beginning, with the mixing diminishing as the process approaches the end of the cycle. In many instances the speed of the process must be altered to suit a special treatment, a condition that is particularly well handled by compressed air.

Consider an aerator-flocculator similar to that shown in Fig. 2. It consists of a compressed air header, A, which emits a controlled air stream. The air causes the water and flocculation material to swirl in the tank, with baffles B and C directing the movement of the water to assure correct mixing. Aeration and flocculation take place simultaneously, and can be varied easily for current water conditions by either automatic or manual means. With automatic operation, the personal equation of error is reduced, if not eliminated entirely, offering a foolproof system.

Reduced Contamination

The complete absence of moving parts in this, as well as the aeration systems, is particularly attractive from the standpoint of maintenance. Furthermore, contamination of the water is practically non-existent. Aftercooling and separating devices remove entrained impurities from the air stream prior to its reaching the distribution point. Filters are available that will go further in cleansing the air by removing fine dust particles, and even undesirable odors.

Completely oil free air, through the use of carbon ring, non-lubricated compressors, will further preclude the possibility of water contamination and clogging of delicate control instruments by lubricating oil. The cast-iron piston rings are replaced by segmental carbon rings sliding on a honed cylinder bore that requires no lubricant. Piston rod packing is also made up of carbon rings (sometimes hemp), and positive protection can be had by inserting an extra long housing between the cylinder and the compressor frame, so that no part of the rod which enters the crankcase also enters the cylinder. A collar on the rod prevents oil from creeping along it into the cylinder packing box and bore.

Chemical Handling

The special construction mentioned in the preceding paragraph is sometimes necessary on compressors engaged in chemical transmission, particularly that type known as tank car unloading. Here the compressed air is piped to the top of the tank car, forcing the liquid inside to leave the car through another pipe extending to the bottom of the tank. This latter pipe is connected to the storage tank in the area of use, so that the liquid chemical is rapidly moved from place

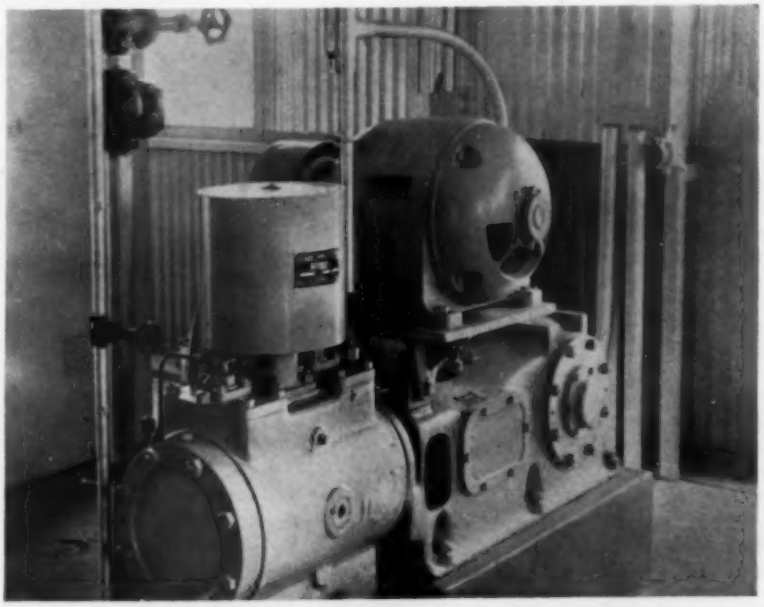

Fig. 3—NON-LUBRICATED instrument air compressor of heavy-duty type capable of delivering 1,245 cubic feet per minute at 60 psi discharge.

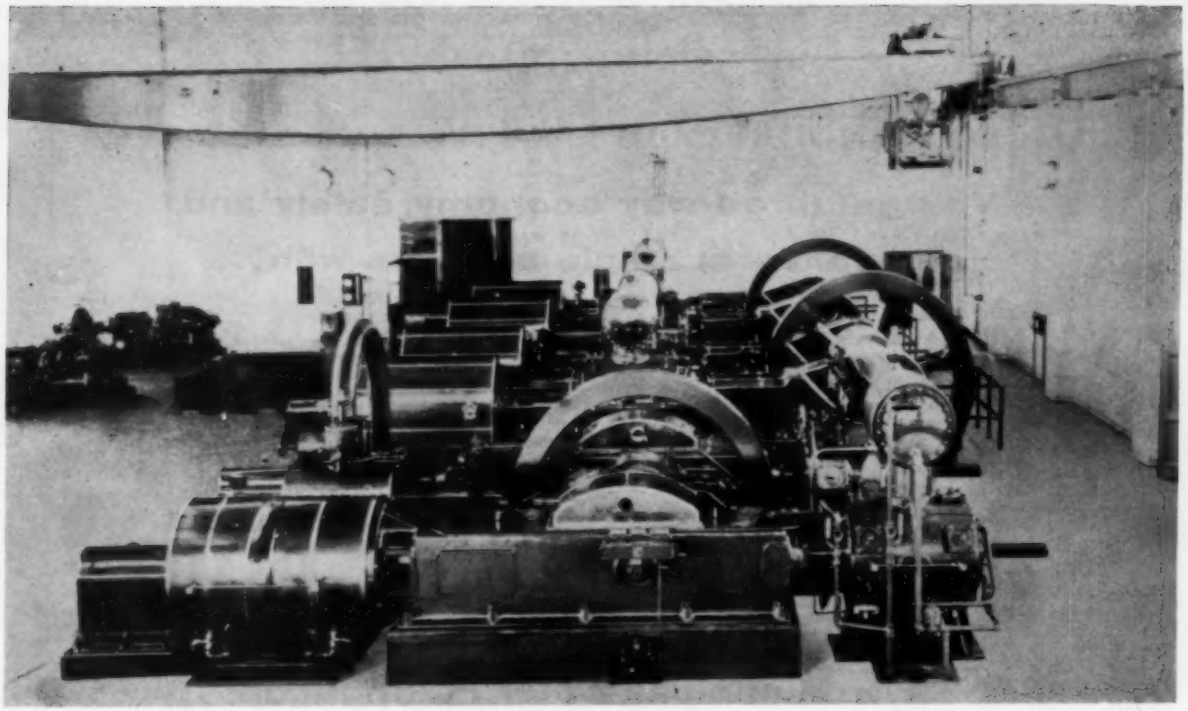

Fig. 4—STEAM-DRIVEN compressors on air lift pump service in a large southern city

to place without the use of expensive special pumps that are used only periodically.

Dry chemicals are skillfully and easily moved by canvas conveyor belts that are fluffed by compressed air.

Vacuum pumps also will handle chemicals with neatness and dispatch by creating a pressure differential between the chemical storage tank and the atmosphere. A hose attached to the tank sucks the chemical in, much in the manner of a giant-sized vacuum cleaner.

Chemical transfer by air pressure eliminates the human element that sometimes results in loose handling and slop-over, both of which are reflected in the overall cost of the chemical. Workers are also protected from the dangers of handling corrosive chemical agents, greatly enhancing plant safety practices, and compressed air never becomes tired.

Maintenance Tools

Maintenance, of course, has always been an important function of compressed air. In the use of maintenance tools, air is unequalled as a source of power. Lightweight construction, high speed operation, and freedom from electric shocks are important arguments in favor of compressed air.

Portable compressors constitute one of the greatest assets of the maintenance sections. Pavement breaking, rock drilling, and earth tamping are all facilitated by compressed air equipment at the site.

Pumping out water-filled excavations can be accomplished by portable units operating miniature air lift pumps. Maintenance of the equipment is thus kept to a minimum; large stones, gravel and broken concrete are easily handled without fear of blade or piston breakage as would be the case with centrifugal or reciprocating liquid pumps.

Miscellaneous Uses

Compressed air does not stop with those functions directly concerned with pumping or treating water.

Boiler feed control instrumentation, soot blowing, boiler tube cleaning, and ash removal all can be handled automatically with compressed air.

Carbonaceous material adhering to boiler tubes must be blown off if the steam generator is to perform at peak efficiency. Compressed air, although having a somewhat greater initial cost in some cases, permits the use of low temperature, uninsulated piping and does away with the waste of high-pressure steam. Compressed air soot blowing also has a lower operating cost than a steam cycle.

Control and instrumentation also belong among the water works components serviced by compressed air.

Exceptional sensitivity, dependability, and low cost have all contributed heavily to the use of air controlled and operated chlorinators, traveling screens, chemical mixers, boiler feed pumps, water pump discharge valves, and similar station equipment. By means of Bourdon tubes, bellows, and diaphragm needle valves, all air activated, pressure changes within a system are quickly picked up and magnified, so that sensitivity of less than one per cent is easily achieved.

A Versatile Tool

From street pavers to such simple functions as blowing the dust from a workman's bench, compressed air occupies a prominent position in the water works field. But with all its inherent ruggedness and built-in long life, the compressor must rely on the consideration of the operator and engineer to offer its maximum efficiency.

Intake filters to keep the cylinders free from abrasive dust; the proper amount and temperature of jacket cooling water (on water cooled units) to prevent overheating and moisture condensation; aftercoolers, separators, and traps to insure clean dry air being supplied to the end point; air receivers for storage purposes and pulsation damping; and a strict maintenance schedule that will assure periodic inspection of the compressor, inside and out, are all vital to the proper operation of the compressor.

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Hydrofluosilicic Acid For Water Fluoridation

by C. E. MEGINNIS

Applications Engineer, Davison Chemical Co., Baltimore, Md.

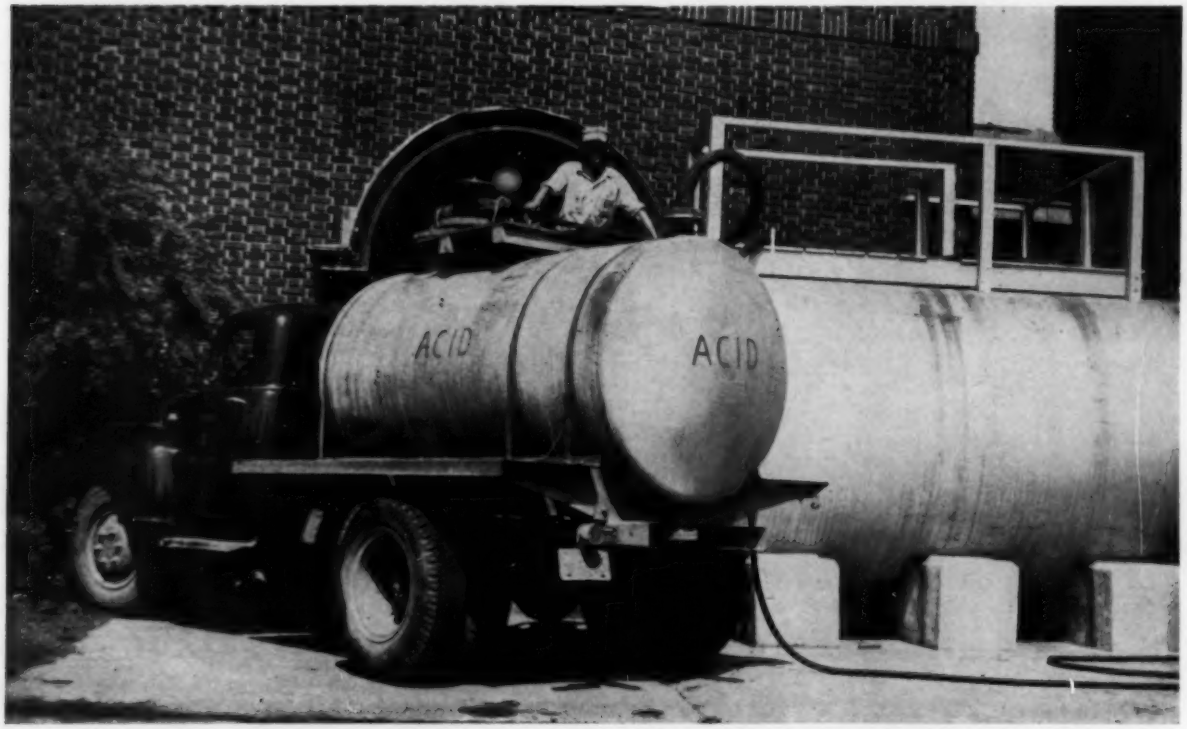
THE GROWTH OF WATER FLUORIDATION has focused attention on the relative merits for this purpose of the various fluoride compounds. Recently, the trend has been definitely toward choice of hydrofluosilicic acid. Not only the large installations for fluoridation, but also goodly proportion of the smaller ones have been engineered for the acid. Evidently, this is the form which most satisfactorily meets the engineer's various criteria of convenience, cost, safety and effectiveness.

In view of the trend noted, it should be of interest to consider something of the source materials and chemical derivation of hydrofluosilicic acid, as well as its characteristics for water treatment.

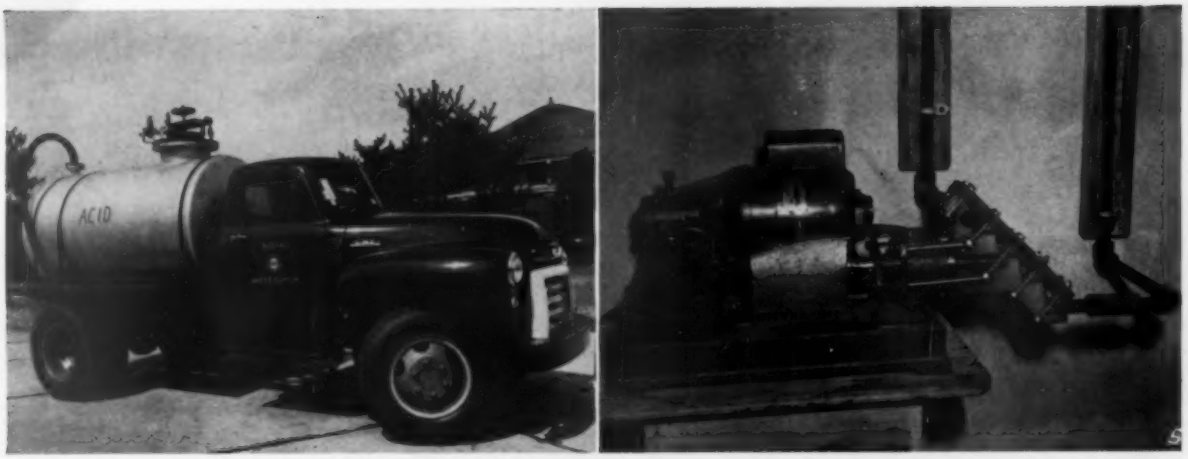
Source of Fluosilicic Acid

Fluosilicic acid has customarily been derived from processing of superphosphate, which is, of course, a basic inorganic fertilizer. In view of the rapidly rising production and use of the acid from this source, it is now more accurate to call it a co-product than a by-product. The raw materials for superphosphate production are sulfuric acid and phosphate rock. The latter occurs naturally in many areas throughout the world; in the United States principally in Florida, Tennessee and Idaho. The most significant rock deposits in America are in Florida and contain 30 to 35 per cent phosphorous, as phosphorous pentoxide (P_2O_5), and 3.5 per cent fluorine (F). After the phosphate rock is mined, it must be ground to substantially pass a 100-mesh screen to speed up its reaction with a 72 per cent concentration sulfuric acid. After acidulation, the mix is held for several weeks to allow for completion of the chemical reaction and the fixing of hydration water. During acidulation and curing, about one-half of the fluorine in the rock is converted to silicon tetrafluoride gas and recovered as weak fluosilicic acid by washing the gas with water.

The acid recovery ratio is low, averaging 10 pounds of 100 per cent hydrofluosilic acid (H_2SiF_6) per ton of superphosphate produced. But, since the production of superphosphate is estimated to be somewhat in excess of 10,000,000 tons each year, it would be possible to make available more than 50,000 tons of 100 per cent hydrofluosilicic acid. To indicate the magnitude of the potential supply, it suffices to note that Chicago will need approximately 2,000 tons per year of 100 per cent acid, or just 4 per cent of what can be made available.



STORAGE and transportation of hydrofluosilicic acid is in rubber-lined tanks

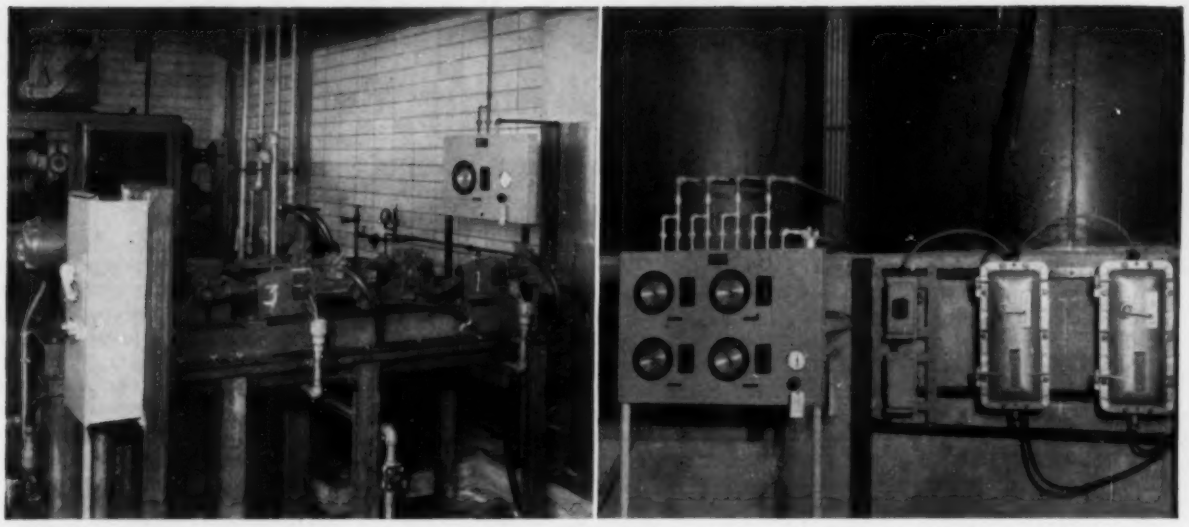


RUBBER-lined tank truck (left) and solution feeder (right) constitute only mechanical equipment for fluoridation of water by use of fluosilicic acid

Once the weak fluosilicic acid has been recovered, it must either be concentrated to a marketable level of at least 22 per cent H_2SiF_6 or converted to a desirable commodity such as the insoluble or soluble salts. The conversion to insoluble salts, sodium and potassium, is readily accomplished by adding the proper amount of sodium or potassium chloride. The insoluble sodium or potassium silicofluoride simply precipitates out of solution and is classified and dried. Soluble salts, ammonium, magnesium and zinc, are considerably more difficult to manufacture because there is an evaporation step which gives rise to a multitude of production problems, one of the worst of which is equipment corrosion. The concentration of the acid is a relatively new technique and requires special equipment and know-how.

Prior to the establishment of fluoridation procedures by the city of Baltimore*, based on the use of hydrofluosilicic acid, we at Davison found ourselves in a unique position. Although we were the only manufacturer of a complete line of silicofluorides (salts

UNLOADING tank-car of hydrofluosilicic acid to storage tanks—Chicago's Southside Filter Plant.



METERING PUMPS (Milton Roy) delivering correct dosage of fluosilicic acid to water and (right) storage tank elevation guages and chemical pump controls—Chicago's Southside Filter Plant.

as well as the acid) we had recommended and sold only sodium silicofluoride for fluoridation purposes. Nevertheless, we were convinced, through both a rigid analysis of the controlling factors and typical reactions from municipal water people, that the acid approach would be superior to the dry feed method. Therefore, we worked closely with the City of Baltimore (the home of the company) to help promote the cause of acid fluoridation. The outcome is a matter of record: Baltimore's experience was eminently successful. Then followed Philadelphia, St. Louis and, more recently, Chicago.

Controlling Factors in Selecting Fluorine Compounds for Water

Let us treat for a moment the prime factors involved in selecting a material for water fluoridation. There are a number of fluorine compounds available: sodium fluoride, hydrofluoric acid, sodium silicofluoride, ammonium silicofluoride and hydrofluosilicic acid. The primary questions raised concerning them refer to dependable availability and price stability; economy; flexibility in use; handling problems, and safety. So far as availability and price stability are concerned, the astonishing amount of acid potential in this country has already been mentioned. Furthermore, the production of fluosilicic acid has been stressed, so it is now considerably more than a secondary product. A third factor is the sparcity of industrial hydrofluosilicic acid application, while industry strongly competes in the case of the other compound which can be used for water fluoridation.

From the standpoint of product cost, sodium silicofluoride is the only chemical in the group which is less expensive (about 7 per cent) than fluosilicic acid. However, equipment, installation, maintenance and labor costs are so much less when the acid is used that there is little true competition.

As to flexibility in use, the acid may be applied irrespective of plant capacity. Because of its unlimited solubility, the smallest of plants can use it successfully, whereas salt solubility would present a definite limitation. As to handling problems and safety, fluosilicic acid is a transparent, straw colored, corrosive but essentially non-fuming liquid. Ordinary precautions, such as the use of rubber gloves, safety glasses and protective clothing, should be practiced when working with the acid. However, it is unlikely that a worker will have any occasion to come into contact with the material.

In large installations, tank cars or tank trucks of acid will be unloaded, either with air pressure or by pumps, into rubber-lined steel tanks which are vented to the atmosphere. An accurate proportioning pump will feed the acid direct from the storage tank into the filtered water. There are several types of construction materials suitable for corrosive resistant equipment which can be utilized by a water utility or the manufacturers of pumps, valves, pipes and tanks.

For small communities, the standard rubber or polyethylene-lined shipping drum may be used as the storage tank. The acid can be withdrawn by placing a Saran or rubber hose in the drum and pumping it out with a positive displacement metering pump.

Use of the liquid fluosilicic acid eliminates the expense of dry feed equipment, the high cost of labor in handling, the inherent difficulties of powder feeding, and the hazards of toxic dust.

Based on the considerations of availability and price stability, economy, flexibility in use, handling and safety, hydrofluosilicic acid appears to be the overall first choice for water fluoridation.

* "How Baltimore Fluoridates." W.&S.W., Nov. 1954.

Use of Inhibitors in Cleaning Metallic Pipe

by ALLEN ABRAMS and C. L. WAGNER

Marathon Paper Mills Co., Rothschild, Wis.

WATER pipes in certain sections of the country are likely to become clogged by corrosion or deposits from the water. In many cases this has required replacement of the pipes, a procedure which is often costly due to the necessity of tearing out walls and floors. As a result there have been attempts to clean pipes by the use of muriatic or other acids with the intent to leave the acid in just long enough to remove the scale and yet not long enough to attack the pipe itself. This, however, is a questionable expedient and may be more expensive than the replacement of the pipes.

Considerable interest has long been shown in the use of inhibitors in pipe cleaning operations involving acid treatment. These are usually nitrogenous materials such as aniline or pyridine; and, even glue and flour have been used. When small quantities of such substances are added to an acid solution the resultant mixture will attack rust or scale but will have practically no effect on the pure metal itself. Wide use has therefore been made of this principle in the acid process of "pickling" metals to effectively remove scale while rendering the loss of metal underneath almost negligible.

An example has been given of the use of this principle in cleaning the pipes of a thirty-five story office building located in downtown New York.*

Many of the pipes were concealed behind expensive marble walls and it was estimated that it would cost between $100,000 and $300,000 to replace this piping, not to mention the serious inconvenience to tenants. By the use of an acid-inhibitor combination the whole cleaning operation was carried out on Saturday afternoon without inconvenience to the tenants. The pipes were returned to practically their normal condition of carrying capacities and the cost of the operation was but nominal.

This method attracted our attention and we made initial tests to determine how effectively inhibitors would reduce the action of acid on the metal. In parallel tests on galvanized iron pipes 16 per cent muriatic acid was used alone, to compare with the same acid containing 3 per cent of an inhibitor. Equal lengths of pipe were allowed to stand in each solution for six hours. At the end of that time the pipe in muriatic acid had lost 50 per cent of its weight while that in the inhibited acid had lost but 0.2 per cent of its weight. We were then satisfied that the inhibitors would effectively prevent destruction of the pipes by such acid when submerged for a relatively short period.

Working Demonstrations

Not long afterwards two lengths of pipe, leading from the basement of our main office to the second floor became filled with rust and other deposit, completely stopping the passage of steam. It would have been relatively expensive to replace this piping and we therefore opened the two lengths at the top and cleaned them by pouring in inhibited acid, allowing it to work its way through. One overnight treatment, followed by a thorough flushing was sufficient to clean these pipes and no further trouble was encountered.

When the Marathon County Board decided that it would be necessary to tear out and replace all the water piping in the Mount View Sanatorium due to the fact that it was so stopped up that it was impossible to get an adequate water supply through the system, we suggested that an attempt be made to clean several lengths of this pipe and a decision could then be made as to the further course to be pursued.

Twenty-five gallons of 14 per cent muriatic acid were treated with 3 per cent, by volume, of the inhibitor.** The treated acid was placed in a barrel to which was connected the suction of a small rotary pump. The acid was then forced upward from the basement to the second floor through a length of one-inch pipe, thence through a cross-over and down through another length of pipe to the basement. The returning acid passed through a fine screen to remove any dislodged particles and thence to the solution barrel.

At the beginning of the test a considerable amount of solid material was dislodged from the pipes and it was almost impossible to force the acid through. The pipes were then opened on the second floor, the acid mixture was poured in and allowed to flow by gravity until the pipes were filled. The bottom openings were plugged, the acid allowed to stand for eight hours and the acid withdrawn and the pipes thoroughly flushed. Examination indicated that the scale had been practically completely removed.

Control Procedure

In order to determine how effectively the cleaning was being done, three 6-inch lengths were cut from a 1-inch pipe, which was so clogged with rust and dirt that it was barely possible to get a pencil into the opening. One of these pipes was retained without treatment and the other two were connected in the circuit through which the acid was being pumped. At the end of about two hours one length of pipe was removed and found to be almost completely clean except for small patches of rust on the walls. After ten hours the other length of pipe removed for examination proved to be entirely free of rust and scale and there was no apparent action on the metal itself.

In the cleaning operation approximately 2,800 feet of pipe were treated, ranging from ½ inch to 4 inches in diameter. Estimates showed that the total labor costs were $870, while the cost of acid and inhibitor was approximately $20—a total of $890.*** It was estimated that the cost of replacing the piping would have been:***

Galvanized pipe fittings and valves	$1,000
Labor for installation	5,000
Plaster, concrete floor and repainting	2,500
Total	$8,500

*"Removing Rust from a System with Piping Acid," F. N. Speller, E. L. Chappell and R. P. Russell—Chem. and Met. Engineering, July, 1927.

**Inhibitors are available, from several of the larger chemical companies—Barrett & Co., Monsanto Chemical Co., General Chemical Co., et al.

***1957 costs would be considerably higher.

Plastic Test Bottle For Chlorine Leaks

by A. A. HIRSCH
Water Purification Superintendent, Department of Water and Sewerage, Shreveport, La.

THE IMPORTANCE of testing for and locating leaks in gaseous chlorination apparatus, followed by their immediate repair, is well appreciated by all water and sewage plant operators. Devices used for spotting leaks have been, until recently, cotton swabs moistened with ammonium hydroxide or a bottle containing this material held with mouth open close to the suspected spots. The tell-tale white fumes of ammonium chloride pin-points the leak.

New Type Container

A newer container for holding the ammonia water is a polyethylene blow-bottle having a perforated top. The bottle is only partly filled with liquid so that pressure on the flexible sides ejects some ammonia-laden fumes in the vicinity of the leak. Since ammonia tends to escape through the orifice on standing the liquid loses strength and causes a slight odor near by.

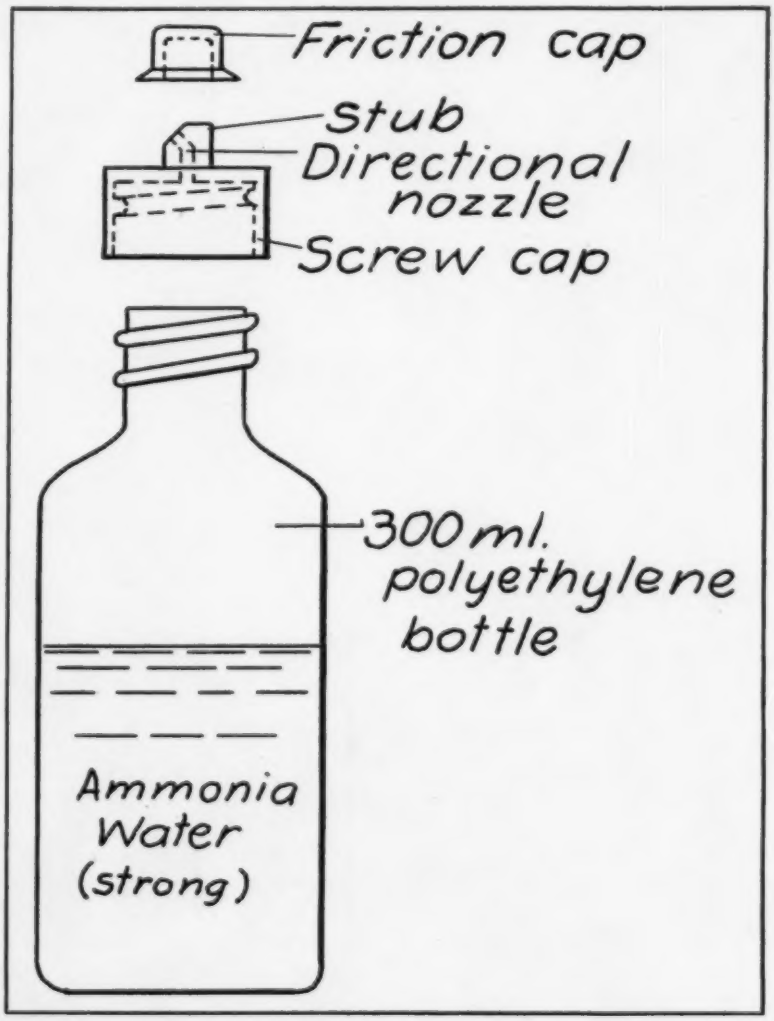
Properly protected, the blow bottle is an ideal device for this purpose; a recommended type of polyethylene bottle is shown in Figure 1. Its capacity is about 300 ml and is two-thirds filled with ammonia. The lid consists of two parts, a screw cap surmounted with a stub through which a hole is offsetted, and a friction cover for this cap. The type illustrated, originally designed as a dropping bottle, was manufactured by the Plax Corporation, 221 N. LaSalle Street, Chicago 1, Ill.

The regular size of mouth permits filling the bottle easily and the cover over the nozzle retains the strength of the ammonia almost indefinitely. Counterboring the nozzle passage as indicated at a 45° angle allows the vapor to be jetted in a convenient direction, and keep the liquid in the bottom for locations where the bottle would otherwise have to be tilted.

Other Modifications

Readily available and simpler modifications, but lacking some of these advantages, may be made from such articles as plastic bottles for ketchup or from a plain, polyethylene bottle with a 1/64 inch hole drilled through the cap. An ordinary steel pin can plug the hole.

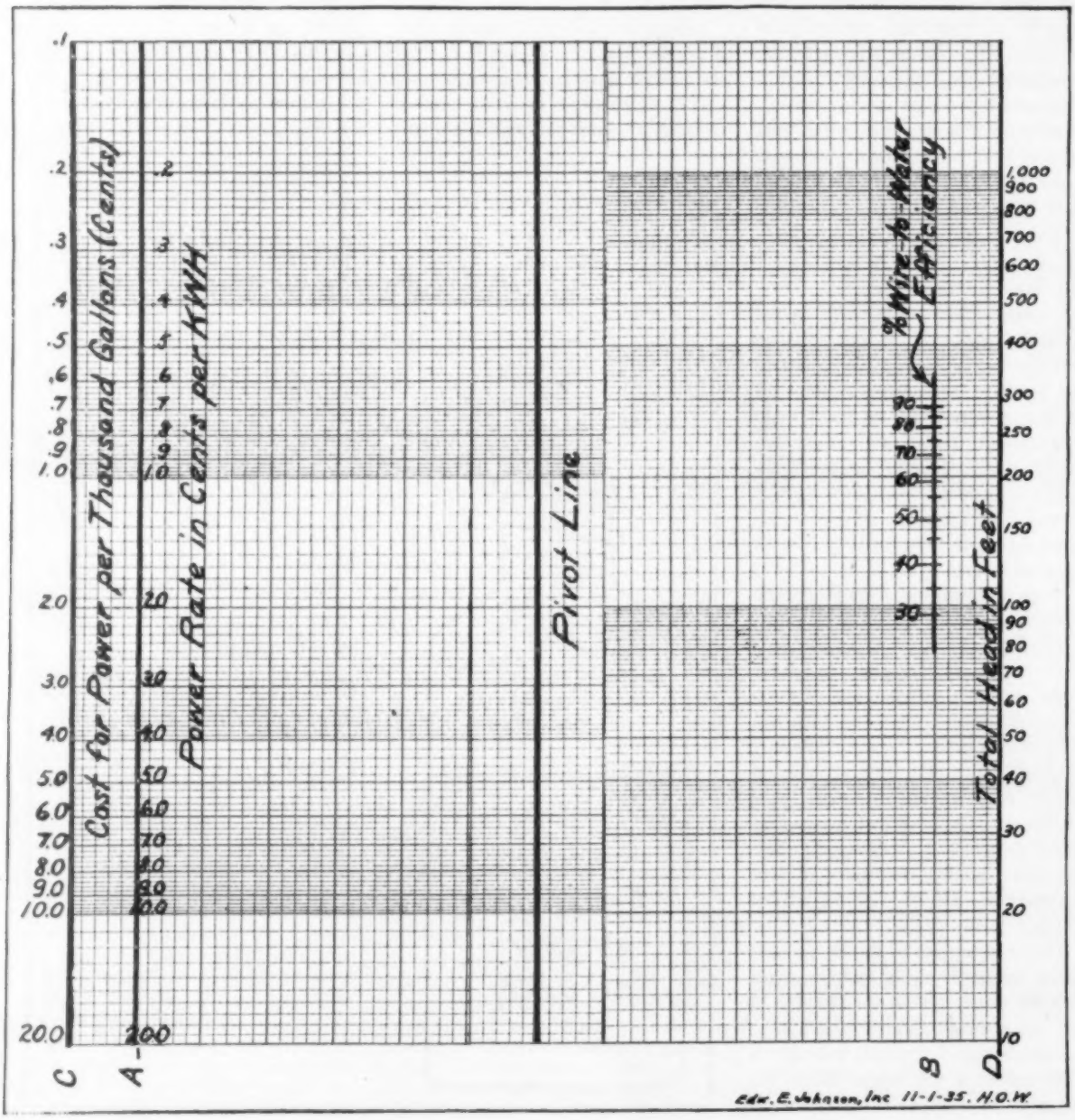
Plastic pocket flasks have been considered on account of their ease in carrying and positioning on a shelf, but they do not squeeze as much vapor volume as do the round bottles of the same size.



POLYETHYLENE blow bottle

Chart for Determination of Pumping Costs

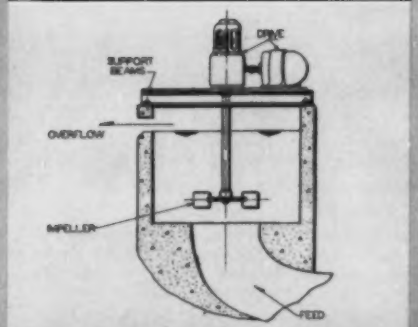
This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



Dorr-Oliver

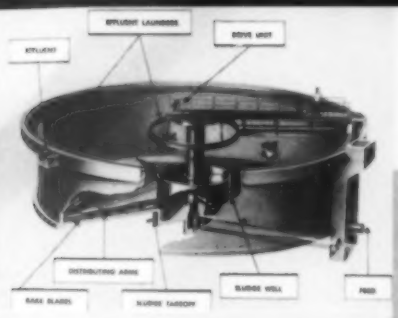
Equipment and Methods for Modern Water Purification and Sewage and Industrial Waste Treatment

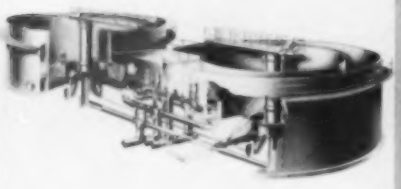
An outline of the major equipment units of the complete Dorr—Oliver line for municipal and industrial sanitation arranged in flowsheet order.

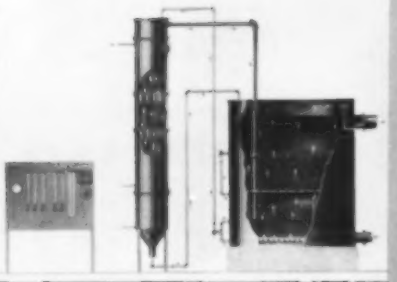


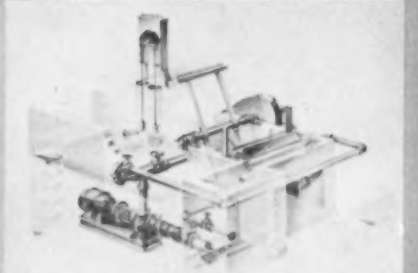
EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
WATER PURIFICATION		
PRE-SEDIMENTATION		
Dorr Pre-sedimentation Thickener Up to 50 MGD and 10,000 tons solids per day per unit.	Raking mechanism for circular tank, designed to collect and concentrate settled material to a central discharge cone.	Particularly adaptable where turbidity exceeds 1,000 ppm. Use results in chemical savings and reduced load on secondary basins.
MIXING		
Dorrco Flash Mixers From 0.5 to 40 MGD per unit. Bulletin No. 6971	High-speed, motor-driven mixing unit equipped with turbine-type impeller for intense mixing in few seconds.	Whenever complete diffusion of chemicals through raw water is desired instantaneously to avoid floc formation in mixing chamber proper.
FLOCCULATION		
Dorrco Flocculator* From 0.1 MGD up. Bulletin No. 6971	Motor-driven revolving paddle wheel elements set in rectangular basin. Gentle mixing causes build-up of uniform flocs of excellent characteristics.	Whenever finely-divided or semi-colloidal solids are present in raw water, the use of Dorrco Flocculators will increase plant capacity and reduce chemical consumption.
CLARIFICATION		
Dorr Clarifiers and Monorakes* From 0.1 MGD to 30 MGD per unit. Bulletin Nos. 6191 and 6001	Both center-shaft and center-pier Dorr Clarifiers equipped with rotating raking arms for round or square tanks. Dorrco Monorake is a balanced raking mechanism for use in rectangular tanks.	Continuous removal of settled solids from clarified raw water, sewage or industrial waste.

Dorr-Oliver equipment and methods are protected by apparatus and process patents issued and pending in the United States and other countries. Copyright 1952 The Dorr Company. Printed in U.S.A. Reprinted 1958 by Dorr-Oliver Incorporated.

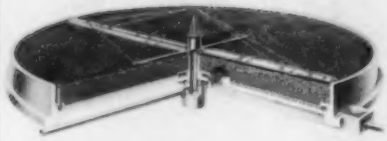


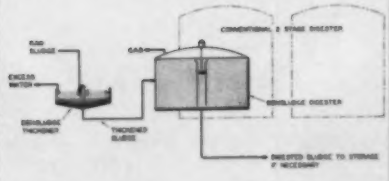


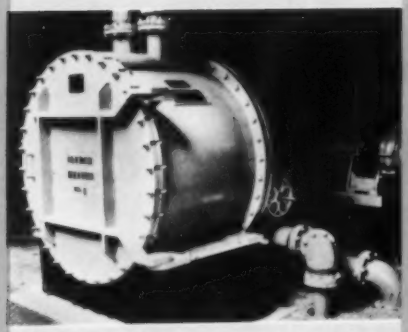


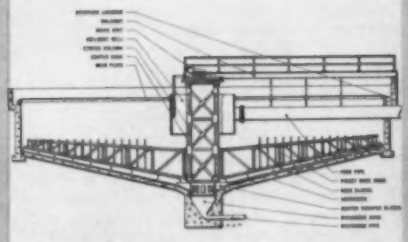


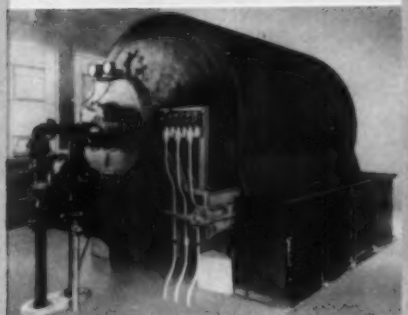
EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
COMBINATION UNITS		
Dorrco Hydro-Treator* From 0.2 to 30 MGD per unit. Bulletin No. 9041	Complete, self-contained high-rate unit providing for flocculation, thickening, clarification and positive sludge removal in a single tank.	For softening, color or low turbidity removal.
Dorrco Clariflocculator*	See sewage and industrial waste treatment.	
Dorrco Aldrich PeriFilter System From 0.1 to 5.0 MGD per unit. Bulletin No. 9042	Normally consists of two or more Dorr pre-treatment mechanisms each surrounded by an annular rapid sand filter.	For chemical pre-treatment followed by sand filtration to remove turbidity, color and hardness.
ION-EXCHANGE		
Dorrco Hydro-Softener From 75 to 800 GPM. Bulletin No. 4083	Uses base or cation exchange resins for continuous softening. Resin is continuously regenerated with brine.	For softening comparatively clear water to make it satisfactory for usual domestic needs.
SEWAGE AND INDUSTRIAL WASTE TREATMENT		
SCREENING AND GRINDING		
Dorrco Bar Screen Up to 75 MGD per unit. Bulletin No. 6400	Mechanically operated automatically activated unit consisting essentially of bar racks cleaned by motor-driven rake.	Every sewage and industrial waste treatment plant where removal of sticks, rags and other large solids is required.
Dorrco Sulzer Disintegrater 60 cu. ft. of screenings per hour. Bulletin No. 6400	Motor-driven, heavy duty screenings macerator. Consists of low-head pump with fixed and rotating cutting blades arranged in front of a perforated screenings plate.	For the maceration of sewage screenings. Especially adaptable in combination with Dorrco Bar Screen.
GRIT REMOVAL		
Dorr Detritor* From 0.25 to 140 MGD per unit. Bulletin No. 6411	Continuous, mechanically operated grit chamber consisting of separate grit collecting and grit removal and washing mechanism.	For the removal of grit of 65 mesh or coarser from raw sewage or industrial waste.
CLARIFICATION		
	See water purification.	











EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
TRICKLING FILTRATION		
Dorrco Distributor From 0.1 to 27 MGD per unit. Bulletin No. 6300	Two or four-arm rotary, self-propelled unit for even distribution of liquid wastes over filter bed.	Equally applicable to low or high-rate trickling filter treatment for oxidizing organic matter in solutions.
SLUDGE DIGESTION		
Dorrco Densludge Digestion System Combines Grit Washer, Densludge Thickener, Digester and Heat Exchanger to meet any sludge digestion problem. Bulletin No. 6262	Incorporates Densludge Process (described below) with integrated digestion control system which reduces capacity requirements up to 80% over conventional methods.	For digestion of organic solids from any primary or secondary treatment flowsheet at maximum volume utilization.
SLUDGE HEATING		
Spiral Heat Exchanger 110,000 to 1,530,000 BTU per hour rated capacity per unit. Bulletin No. 6281	External element for heating of sewage sludge. Consists of two concentric spirals welded together to form alternate hot water and sludge liquor passageways.	Provides simple, high-efficiency and easily controlled means of externally heating contents of any digester.
SLUDGE THICKENING		
Dorrco Densludge Process For plants treating from 0.5 MGD up. Bulletin No. 6260	Clarification and thickening are carried out separately. Dorr Densludge Thickener produces a sludge with up to 50% less volume.	For both activated sludge and trickling filter plants to increase digester capacity and other sludge handling facilities.
FILTRATION		
Oliver Sewage Sludge Dewaterer From 65 sq. ft. of filtering area in "package" units to 570 sq. ft. in standard individual units.	Low submergence drum type continuous vacuum filter available in a variety of corrosion resistant material to meet any sludge dewatering problem.	Removes 80% to 85% of the water from raw or digested sludges produced in any primary or secondary treatment plant.
COMBINATION UNITS		
Dorrco Vacuator® From 0.5 to 30 MGD per unit. Bulletin No. 6301	Cylindrical tank with dome roof employing principle of vacuum flotation. Makes three product separation of floatable material, improved effluent and a sludge containing appreciable quantities of grit.	For scum and grit removal ahead of primary sedimentation; for complete primary treatment; for sole treatment in coastal areas.

EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
COMBINATION UNITS Cont'd.		
Dorrco Clariflocculator From 0.1 to 10 MGD per unit.	Provides mechanical flocculation in inner compartment, clarification and positive sludge removal in outer annular compartment.	For clarifying raw or chemically treated municipal and industrial wastes.
Dorrco Aerator-Clarifier From 0.1 to 7.5 MGD per unit.	Contains cylindrical aeration chamber of steel with partially closed bottom, concentric with Clarifier. Standard sludge raking mechanism. Air introduced by fixed diffuser tubes.	For the preaeration of raw sewage. Grit or heavy solids will not interfere with operation of unit.
Currie Claractor Up to 25 MGD per unit. Bulletin No. 6581-C	Combination aerator and clarifier with clarification taking place in round or square central compartment and aeration in outer annular compartment.	For the clarification and aeration of sewage or industrial wastes in the activated sludge process.
Dorr Clarigester* From 0.1 to 1.25 MGD. Bulletin No. 6691-C	Mechanically equipped two-story tank combining clarification in top compartment and controlled, separate sludge digestion in lower compartment.	Ideal for small sewage or industrial waste plants either as sole treatment unit or in combination with other treatment steps.
Dorr Duo-Clarifier Duo-Filter and Duo-Clarigester From 0.1 to 1.25 MGD per unit. Bulletin No. 7312	The "Duo" units are designed for two-stage treatment in a single structure. The Duo-Clarifier provides primary and secondary clarification in one tank; the Duo-Filter consists of two stages of filters arranged concentrically; the Duo-Clarigester provides two stages of clarification plus separate sludge digestion in a single structure.	Particularly adaptable for treatment of domestic sewage from small communities and isolated establishments with contributing populations of over 500 and industrial wastes requiring biological treatment.

for more detailed information, write, wire or phone the nearest of the following offices . . .

Stamford, Conn.	Barry Place	St. Paul 4, Minn.	2631 University Avenue
New York 16, N.Y.	99 Park Avenue	Denver, Colo.	P.O. Box 149 (Englewood)
Atlanta, Ga.	900 Peachtree	Dallas 2, Tex.	6115 Berkshire Lane
Cleveland, Ohio	1032 Midland Bldg.	Los Angeles 14, Calif.	811 West 7th Street
Chicago, Ill.	942 Merchandise Mart	Oakland, Calif.	2900 Glascock St.
		Seattle 4, Wash.	3104 Smith Tower

Dorr-Oliver
INCORPORATED

OFFICES, ASSOCIATED COMPANIES OR REPRESENTATIVES IN THE PRINCIPAL CITIES OF THE WORLD

*TRADEMARK REG. U. S. PAT. OFF.

V. SEWAGE WORKS OPERATIONS

SEWAGE is the used water supply of a community. It must be deposed of without nuisance. In this disposal process many functional operations are performed as well as a number of operations which may be considered as peculiar to sewage treatment. In the following section articles and basic data are presented on these operations and processes.

Inasmuch as space does not permit the inclusion of all good reference articles and data in one issue, the reader should refer to the previous three issues of the Reference & Data Numbers of *Water & Sewage Works*. The following outline of sewage works operations shows the broad areas and phases covered in this section.

OUTLINE OF SEWAGE WORKS OPERATIONS

I. Characteristics

A. Physical
1. Color
2. Odor
3. Solids
4. Temperature

B. Chemical
1. Biochemical Oxygen Demand
2. Alkalinity and pH
3. Chlorine Demand
4. Other

C. Bacteriological
1. Putrefactive
2. Pathogenic
3. Coliform
4. Aerobic
5. Anaerobic

II. Stream Pollution

A. Deoxygenation

B. Sludge Banks

C. Bacteriological

III. Collection of Sewage

A. Design and Construction
1. Combined Systems
a. Interceptors
b. Main Trunk
c. Laterals
d. Overflow Chambers
2. Sanitary Sewers
a. Interceptors
b. Main Trunk
c. Laterals
d. Lift Stations
e. Force Mains
3. Storm Sewers

B. Operation
1. Combined Systems
2. Sanitary Sewers
3. Storm Sewers

IV. Sewage Treatment

A. Purpose
1. To remove nuisance
2. To protect health

B. Methods
1. Primary Treatment
a. Grit removal
b. Screenings removal
c. Sedimentation
(1) Sludge removal
2. Secondary Treatment
a. Trickling Filters
(1) Standard rate
(2) High rate
(3) Roughing
b. Activated Sludge
(1) Standard
(2) High rate
(3) Tapered Aeration
(4) Step aeration
(5) Other processes
3. Disinfection
a. Chlorination
b. Control
4. Solids Disposal
a. Screenings
b. Grit
c. Skimmings
d. Sludge
(1) Digestion
Gas production and utilization
(2) Dewatering
(3) Elutriation
(4) Drying
(a) Natural on beds
(b) Furnaces
Flash Dryers
Multiple Hearth
(5) Incineration
(a) Flash Dryers
(b) Multpile Hearth
(6) Ultimate disposal
(a) Sludge as fill
(b) Sludge as fertilizer
(c) Ash as fill

C. Operation and Control
1. Laboratory control
a. Tests
b. Results
2. Supervision
3. Maintenance

How to plan sewage, water and FOR THE

Specify LINK-BELT equipment . . . lasting, efficient, flexible

IN many cities, growing populations have required expandability to be designed into water and sewage treatment systems. Increasing production, plus anti-pollution measures, creates much the same situation in industrial waste treatment. The broad range of long-life Link-Belt sanitary engineering equipment is helping to meet these requirements—permitting design flexibility that provides for easy enlargement with minimum changeover.

Our sanitary specialists will work with your own engineers, chemists and consultants. For more details, call your nearest Link-Belt office.

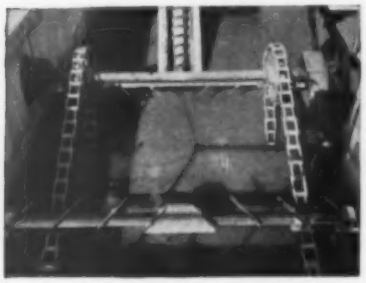
OTHER LINK-BELT PRODUCTS INCLUDE: Scum breakers, air diffuser units, non-clogging spray nozzles, traveling water intake screens, Roto-Louvre sludge dryers, chemical handling machinery, car spotters and haulage systems . . . Catalogs sent on request.

This Eastern sewage plant had to provide practical sewage treatment for a population of 870,000—yet be able to serve an estimated 1,200,000 expected by 1970. Link-Belt supplied screens, grit collectors and sludge collectors to handle 136 mgd.

LINK-BELT

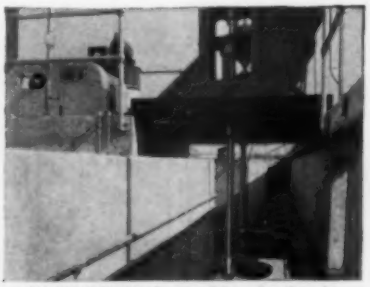
SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,570



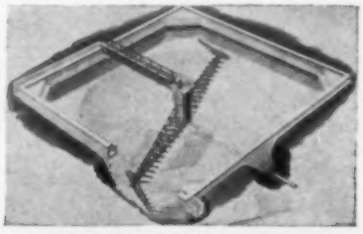
GRIT COLLECTORS AND WASHERS effectively collect and wash settled grit and separate it from putrescible organic matter before removing.

STRAIGHTLINE MIXERS for rectangular tanks, cross or transverse horizontal flow. Degree of mixing can be varied to produce maximum size floc.



FLASH MIXERS thoroughly mix chemicals prior to flocculation . . . prepare chemicals and water for immediate flocculation.

STRAIGHTLINE COLLECTORS for rectangular settling tanks feature peak-cap bearings, pivoted flights and Straightline action for top efficiency.



CIRCULINE COLLECTORS for square or round tanks provide positive sludge and scum removal in shortest time without septicity.

BIO-FILTRATION SYSTEMS utilize high-rate shallow filters . . . recirculation of effluent from filter to primary settling tanks . . . recirculation from final tank to filter. Single- or two-stage.

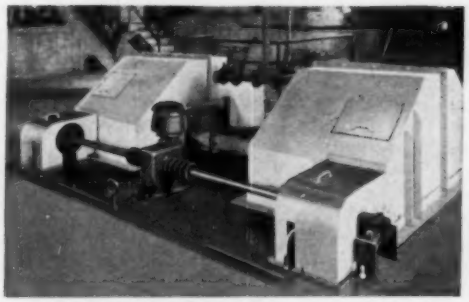
waste treatment facilities
YEARS AHEAD

THRU-CLEAN BAR SCREENS remove large floating particles from large volumes of water, thus protect other equipment from damage.

STRAIGHTLINE BAR SCREENS can't jam, assure constant, automatic screenings removal under extreme conditions.

TRASH SCREENS are operated intermittently for removing large floating debris to protect water screens and other equipment from damage.

TRITOR SCREENS remove both grit and screenings with one mechanism. Shredder can be furnished to shred screenings when no grit is received.



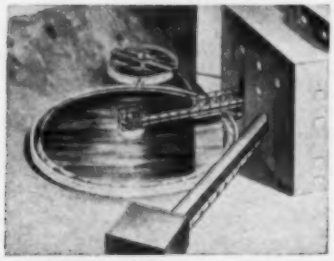
ROTARY DRUM SCREENS remove large quantities of fine solids from surface water intakes, settling tank effluents and industrial wastes. Extremely low maintenance requirements.

REVOLVING DISC SCREENS offer a low cost, low maintenance method of removing solids from sewage effluents used as utility water . . . prevent clogging of foam spray nozzles in aeration tanks.

LIQUID VIBRATING SCREENS are widely used for removing fine solids from liquids. Several sizes, with fine cloth.

SCREW CONVEYORS AND BUCKET ELEVATORS meet the need for efficient handling of lime, alum and other chemicals where space is limited.

BELT CONVEYORS are one of various types of conveyors available for handling bulk or bagged chemicals, sludge filter cake or sludge from drying beds.



THICKENERS AND CLARIFIERS are made in several types and various sizes, including rake and flight types, for high efficiency and low cost operation.

CHAINS AND SPROCKETS as on this mill scale collector or for any conveying or power transmission need can be found in Link-Belt's complete line.

POWER TRANSMISSION PRODUCTS include enclosed gear, fluid and variable speed drives; bearings; chain drives as used on this vertical Straightline mixer.

The Impact of New Industry on Water Supply and Pollution *

by B. A. POOLE

Chief Engineer, State Board of Health and Technical Secretary of the Stream Pollution Control Board of the State of Indiana.

OUR RAPID increase in population in the last few years, our increased standard of living, the phenomenal expansion of industry, the increased crop yields as a result of supplemental irrigation and the droughts of recent years have all contributed to the realization that water will play the predominant role in the economy of the state of Indiana in the next fifty years. Contrary to popular opinion we still have about as much water as we always had. Its use, however, has intensified to such an extent that we must develop what we have and properly manage it if future generations are to be unhampered in its use.

Public Water Supplies

It is a known fact that some Indiana municipalities, particularly in southern Indiana, cannot continue to expand or for that matter cannot attract a single water-using industry until additional sources of water are developed. It is also well known that much of southern Indiana has no ground water to develop. And the supply is by no means unlimited in many other portions of the state. Fortunately we have plenty of rain and there are few localities where an impoundment can't be made at a reasonable cost. We have no insurmountable water supply problem. All we need to do is store some of our flood flows and release them when we need them.

There are 397 Indiana municipalities served by public water supplies that come from 360 sources. These supplies serve 2,500,000 people. In 1953, 60 of these sources experienced shortages of one kind or another, most of them due to inadequate supplies. Some difficulties were caused by inadequate pumping or purification works, inadequate storage of finished water or undersized mains. Forty of the 60 have made improvements. Some of these are good for a long time even with sizable expansion. Others won't accommodate five years of normal growth. In addition to the 60 that had difficulty in 1953 we have another 60 small towns limping along on only one well. And in a few of these the attitude prevails that the pump on this well will run forever!

Droughts are almost invariably blamed for water shortages, with little thought given to increased consumption although it is usually the real offender. The population of Indiana is increasing 60,000 to 80,000 each year, and water consumption is going up at a rate of 2.1 gallons per person per year. In cities above 100,000 water use is increasing at a rate of 3.3 gallons per capita per year. By 1975 the average daily per capita consumption will be 210 gallons in these cities and 330 gallons per person will be required on the maximum day! In cities between 25,000 and 100,000 the per capita per day increase is 2.3 gallons each year. By 1975 these cities will require an average of at least 190 gal per capita per day. On the maximum day they will require 250 gal per capita. In cities between 2,500 and 25,000 the per capita per day increase is 1.9 gallons each year. In 20 years they will require about 150 gallons per capita per day.

Between 1940 and 1954 the total daily water consumption increased from 198 to 332 mgd. This is an average increase of 5 per cent per year. Obviously a "live" city must plan on more.

While the increase in municipal water consumption has been phenomenal, municipal use is small compared to our industrial use. U. S. Department of Commerce figures for 1953 (Water Use in Manufacturing—Series: MAS-53-3—USDC.) indicate average daily industrial consumption for the state was about two billion gallons. Four and three tenths per cent of this is covered in the municipal figures. The rest comes from industrial supplies. This same report lists the following industries as the top water users as shown below. Other low water users are furniture, printing and publishing, transportation equipment, instruments, machinery and fabricated metals.

These statistics are worth remembering by anyone interested in industrial location. No industry, which will become an asset to a community, is going to locate there until it is assured of an adequate water supply, either from the public water system, or through its own development. If it is willing to develop its own source it will expect an adequate supply of pure, potable water in the homes of its workers.

Wastes

When we put water under pressure we create waste disposal problems. Increased domestic water consumption means more sewage. There are few industries that don't have some

Blast furnaces	24	mil	gal	per	yr	per	employee
Electrometallurgical	22	"	"	"	"	"	"
Alkalies & chlorine	17	"	"	"	"	"	"
Organic chemicals	14	"	"	"	"	"	"
Pulp mills	12	"	"	"	"	"	"
Petroleum refining	11	"	"	"	"	"	"
The lowest water users were:							
Aircraft industry	0.03	"	"	"	"	"	"
Telephone & telegraph equipment	0.05	"	"	"	"	"	"

*Presented before the Industrial Development Conference at Purdue University.

liquid industrial waste. The volume depends on the type of industry. The difficulties in properly handling it depend on the volume and the characteristics of the waste. Cooling water from an ordinary steam generating plant is harmless and produces no ill effects other than possible temperature increases. In contradistinction a nuclear power plant will create wastes many times more toxic than anything ever encountered by man. A meat packing plant produces organic wastes several times as potent as human sewage.

Liquid waste disposal problems fall into two main categories:

1. Getting the wastes away from the establishment, whether it it is a home or a factory building.
2. Changing the characteristics of the wastes so they will not unduly jeopardize any beneficial water use.

With industrial development in any community there is always an accompanying housing development either inside the community or immediately adjacent to it. Housing and population development also present problems of water supply and waste disposal and are therefore worthy of comment.

Sewers

As in the case of public water supply improvements the State Board of Health has worked with cities and towns on sewerage developments for many years. Approval of plans and specifications in both categories is required before construction begins.

Experience has shown that the individual septic tank and absorption system is a very poor substitute for community sewers and sewage treatment. It is expensive, costing about $500 per residence. In many areas of the state it will not give satisfactory performance more than two or three where it will work as long as ten years. There are few areas indeed years without a major overhaul. Consequently, the State Board of Health will not approve individual septic tanks and absorption systems for community type housing developments until all possibilities of a common sewer system have been exhausted.

There is much community housing underway in Indiana that is beyond the reach of the municipal sewers. Wise planning and zoning with firm enforcement of local plans would prevent some of this development, and eliminate many future headaches. This is a local prerogative that isn't assumed in many localities. Where connection to city sewers cannot be made, the State Board of Health requires a community sewer system and a single sewer treatment plant where practicable. The only way maintenance and operation of the system can be assured is through the establishment of some type of trust agreement. Even with these there are many headaches ahead since the operation of small sewage treatment works is conducive to headaches. The Indiana Home Builders Association is currently involved in an attempt to frame legislation to make it easier to establish a responsible agency for the maintenance and operation of community sewerage systems. The home builders are conscientious in their efforts and deserve the support of city officials, Chambers of Commerce, etc.

Extension of city and town sewer systems into the suburbs is the only satisfactory answer to the problem. The two most common stumbling blocks are the inability to finance and trunk sewers that are too small for the additional load. The latter problem can be solved sometimes by requiring the new addition to put in separate, instead of combined, sewers.

Within recent years there have been several laws enacted which simplify the financing problem. Some of these are:

a. A supplement to the sewer service charge act now permits the issuance of revenue bonds to finance local sewers and the levying of a connection charge on the properties served by these sewers. The sewer service charge and revenue bond act is the law used almost exclusively to finance municipal sewage treatment works. Works financed under the law may be constructed inside and outside the corporate limits. However, since it is the intent of the law to provide a means of financing the disposal of a municipality's sewage, the sewage of a subdivision outside the corporate limits must be brought to the city's sewers through works financed by the developer or the area must be annexed to the city. (Sec. 48-4301 et seq; Supplemental act, Sec. 48-4339, Burns Indiana Statutes—1950 Replacement)

b. A law enacted in 1949 as a supplement to the Barrett Law (Indiana's Special Assessment Law) improves the ability of cities to finance local sewers by the special assessment method. The city council may by ordinance declare the percentage of the cost of the sewer project that is of general benefit to the city and particular benefit to the property owners served. The city assumes the primary responsibility for the full payment of principal and interest of the bonds issued to finance the project. Since the contractor is paid in cash the disadvantages of payment in Barrett Law bonds are eliminated. (Sections 48-4431 and 48-4432, Burns Indiana Statutes—1950 Replacement)

c. A 1955 act permits contracts with owners or lessees of property in the vicinity of cities for the provision of municipal services. In return for such services the city receives payments in lieu of taxes. The contracts may run for 15 years in first and second class cities and for four years in the case of others. This permits a city to provide sewer service to an industry, or to a housing developer. (Section 48-701, Burns Indiana Statutes—1955 Cumulative Pocket Supplement)

d. Another 1955 act permits any Board of Works to contract with any owner of real estate within four miles of the corporate limits for the construction of sewers, pumping stations and sewage treatment works. The contract must contain a release of the right to remonstrate against annexation. The important feature is that the party who pays for the original works may be reimbursed by anyone who connects to the system within 15 years. (Section 48-3938, Burns Indiana Statutes—1955 Cumulative Pocket Supplement)

Sewage And Waste Treatment

Waste treatment is supervised by the Stream Pollution Control Board. The work of the Board is done by engineers of the State Board of Health. Its program is based on three essential principles:

1. Prohibit new sources of pollution. The Board does not approve plans for new sewer systems or new industrial waste outlets unless adequate treatment is provided.
2. The elimination of existing pollution.
3. Utilization of receiving waters for the assimilation of treated sewage and industrial waste as long as it does not interfere with any other beneficial water use.

The other states in the Great Lakes Region and the Ohio Basin are enforcing essentially the same type of program.

Municipal Sewage

At present better than 80 per cent of all the sewered population of Indiana is connected to sewage treatment plants. As might be expected the percentage of larger municipalities having sewage treatment plants is much greater than the percentage of the towns, since the Board's program of the last several years has been directed primarily to the larger sources of pollution.

Currently some cities with a population of more than 10,000 have overloaded sewage treatment works; others are nearing capacity. Many still require extensive relief sewer work; seven have no treatment plants at all. The problem of the future resolves itself into expanding sewage treatment works and relieving overloaded sewers.

In the 2,500 to 10,000 population bracket there are 45 cities with sewage treatment plants and 26 municipalities without them. Ten of the existing treatment plants are over-

loaded. Sewers in the smaller municipalities may not cover the entire town, hence the problem of these cities in the future is three-fold: (1) Extension of sewers. (2) enlargement of sewage treatment plants, and (3) installation of sewage treatment plants where they are not available.

There are 35 cities and towns in Indiana with a population less than 2,500 that have sewers and sewage treatment. In this population bracket there are 118 municipalities with sewers and no sewage treatment. In many cases sewers in these areas may serve only 50 to 60 per cent of the town. Hence, their problem resolves itself into rounding out the sewer system and the installation of sewage treatment works.

Industrial Wastes in City Sewers

The matter of handling industrial waste in municipal sewer systems and municipal sewage treatment works is one which deserves careful attention. While the Stream Pollution Control Board recognizes this is a matter which must be settled at the local level, it has some definite views on the subject. As a general policy the Board prefers to see industrial waste handled at municipal sewage treatment plants, *if this can be done without jeopardizing the treatment plant or the stream.* It prefers this approach since experience has indicated that some sewage and industrial waste treatment works are not consistently operated at peak efficiency. And the fewer treatment plants you have the fewer there are to cause trouble. Consequently in the case of any new industrial location the Board will ask that the possibilities of connection to city sewers be explored before industrial waste treatment facilities are designed if it appears that the quantity and characteristics of the industrial waste are amenable to treatment in the city sewage treatment plant. Obviously there is no rule of thumb or standard criterion for a problem of this sort. Each case must be treated individually.

Policies within the cities and towns on the handling of industrial waste vary widely. Some city officials go overboard and are willing to accept any and all industrial waste. Others lean as far in the other direction and don't want anything.

We quite frequently find city officials do not work closely enough with industry in the early stages of industrial plant location. An industry will receive a promise the city will take care of its waste. Then it will learn the city was thinking only of sanitary sewage and is not in a position to handle industrial wastes. In many cases, sewers near the industrial site may be too small. But it is frequently cheaper to build some sewers than to build elaborate industrial waste treatment works. In some cases separation of cooling water may be all that is needed. Basically it is sound practice to consider a minimum of two, and in many instances three, sewer systems within an industrial establishment.

The fact that a city sewage treatment plant is near its rated capacity does not necessarily mean a city should not take on a sizable amount of industrial waste. Like all other things associated with mass production a gallon of sewage or waste can be treated for less money in a large plant than in a small plant. Consequently, it may be to the advantage of both parties to expand the city sewage treatment plant rather than build a separate industrial waste treatment plant. Obviously the industry should pay its just share of the cost of expansion. This will usually be cheaper for the industry than its own treatment works would be.

Separate Industrial Waste Treatment

There are many industries which produce such large volumes of waste that they cannot be handled in a municipal treatment plant. Examples are the primary metal industries (65,000 gallons of water per ton of steel); petroleum refineries (18 gal of water per gal of oil); pulp mills; distilleries; chemical plants; large meat and vegetable packers; and large milk plants. Since many of these industries produce very strong wastes, and a few of them toxic wastes, they are also restricted in location to sites accessible to large streams in order to keep the cost of treatment from becoming prohibitive.

The polluting effects of the majority of these wastes are due to their organic constituents. It is organic material that usually uses up the oxygen in a stream, thereby causing it to become black, foul-smelling and unfit for livestock or fish life. Treatment processes will remove from 30 to 95 per cent of the organic material in waste so the amount of dilution water in the stream determines the degree of treatment that is required. Since no treatment process removes 100 per cent of the organic material we cannot expect satisfactory conditions in a small stream which receives large quantities of even highly treated wastes.

The development of nuclear reactors will bring us face to face with the most toxic material ever handled by man. Unlike other pollutants you can't kill radioactivity by chemical or biological treatment. All that can be done with the intermediate and high level wastes is concentrate them and hold them in safe keeping until natural radioactive decay makes them harmless. In the case of a few elements this is a matter of a few hundred years! Some of the low level wastes, with relatively short half-life, can be held for short periods to permit some natural decay and then be disposed of by dilution. This, plus the large quantities of water usually needed for cooling, pretty well fixes the location of large reactors to sites on large streams.

Considerations Of Importance

Space will not permit a complete dissertation on the handling of industrial wastes. They must be properly handled if we are to preserve Indiana's waters for future generations. All persons involved in industrial plant location should keep the following items in mind:

1. Industries that produce large quantities of waste, or have highly potent wastes, should locate on large bodies of water.

2. The uses to which water are put downstream from an industrial outlet have an important bearing on the degree of treatment required. Example—greater quantities of taste-producing compounds may go into a river downstream from a water works intake than into the same river above the intake.

3. Areas where water supply is short, or where summer stream flows are low, should look for industries which produce small quantities of wastes.

4. The Stream Pollution Control Board should be consulted before industrial sites are definitely chosen in the case of all industries that produce wastes in quantity. We will keep the information confidential. Sometimes a given industry can be easily accommodated on one side of town whereas location on the other will bring on exorbitant waste disposal costs.

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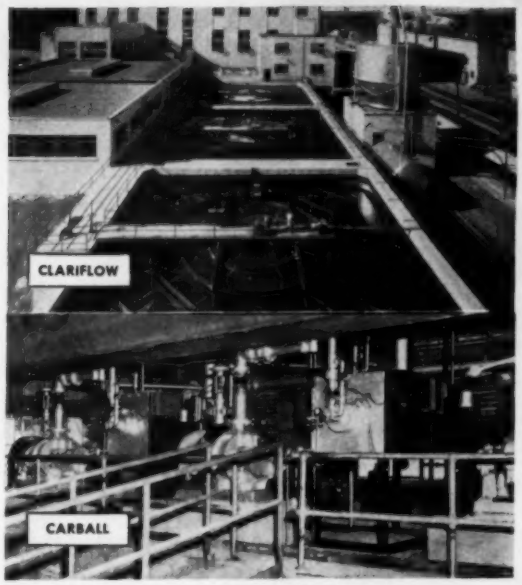

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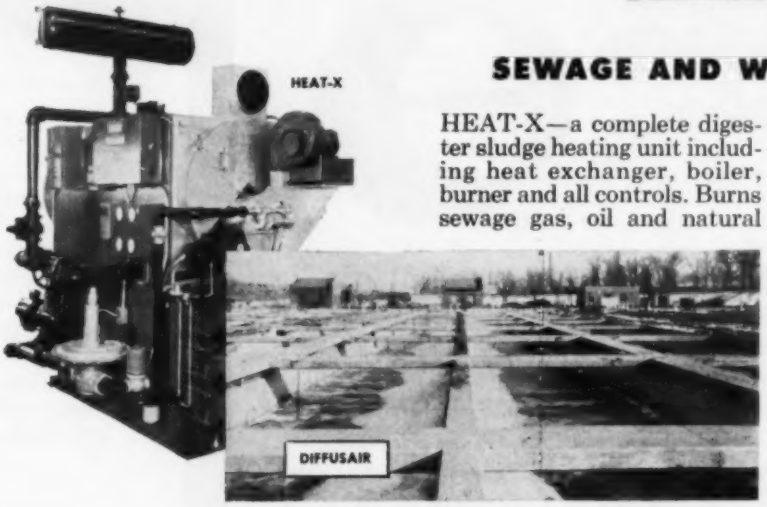

SEWAGE AND WASTE TREATMENT

HEAT-X—a complete digester sludge heating unit including heat exchanger, boiler, burner and all controls. Burns sewage gas, oil and natural gas, singly or in combination. Absolute and independent control over each function of sludge heating.

DIFFUSAIR—aeration equipment for mixing and oxygenation of tank liquors. Self cleaning air Spargers do not clog or cause back pressure build-up on blowers. High rate tank turn-over and oxygenation results in greater plant capacity.

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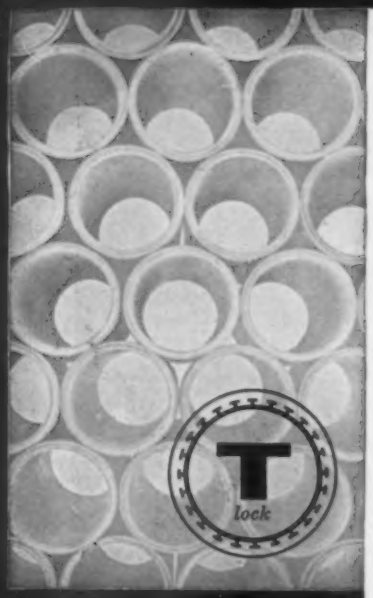
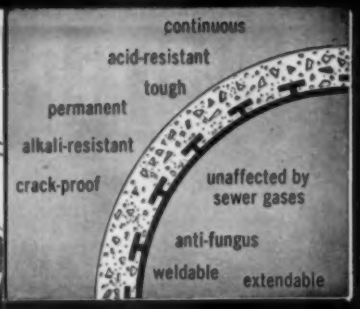


T-lock® sewer lining prevents hydrogen sulfide attack...



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Readily adaptable to complex forms for cast-in-place structures.

T-Lock in place on inner form before pipe is poured.

Control of Hydrogen Sulfide in Sewers

by RICHARD D. POMEROY
Consulting Chemical Engineer of Pasedena, Calif.

MANY ENGINEERS, when they see the type of corrosion that sometimes occurs in sewers, become afraid of the sulfide situation. It is very difficult to reason with fear. An educational program is needed to make the facts known.

Sulfide Generation

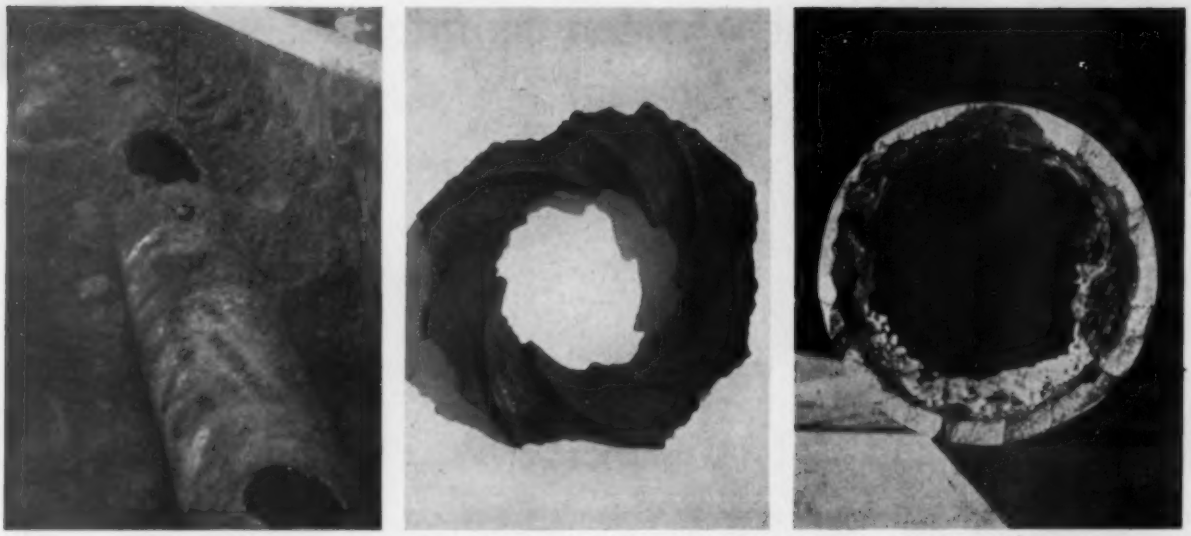
Sulfides are generated in sewage when it becomes devoid of oxygen and sufficient biochemical action occurs so that the bacteria begin to reduce sulfate to sulfide. To think of it in a simple way, glossing over the intermediate steps that may be involved, it can be considered that the sulfate ion is SO_4. It may also be considered that bacteria need oxygen and, when they no longer can get free oxygen from the atmosphere or dissolved oxygen from the stream of water, they will take oxygen away from sulfates. In place of sulfate ions, this will leave sulfide ions, which hydrolize to hydrogen sulfide, H_2S.

The hydrogen sulfide itself is not corrosive to concrete, but the hydrogen sulfide may come out of the sewage stream and be oxidized on the walls of the sewer above the water to H_2SO_4, which is sulfuric acid. On concrete surfaces the sulfuric acid concentrations will not become very high because it will react with the concrete. On a resistant surface the concentration will grow considerably higher.

Enough is known about the factors controlling the formation of hydrogen sulfide so that in many cases it is possible to calculate how much will be produced. In a force main, where there is no chance for the sewage to be in contact with air, there is no surface aeration. In such a situation there will be a build-up of sulfides, even if the sewage is fairly weak and even if the sewage is quite cold, whereas sulfide build-up might not occur in a free-flowing stream. One can calculate quite accurately the amount of sulfide that will be formed in a force main. It is proportional to the strength of the sewage and also is a function of the temperature and the inside area of the pipe.

In a free-flowing sewer there will be no sulfide formation if the sewage gets enough oxygen from the atmosphere above the flowing stream. Several things determine whether or not the sewage gets enough oxygen. First, there is the oxygen requirement of the sewage, dependent upon the strength or the B.O.D. of the sewage and the temperature. Secondly, there is a rate at which oxygen can be absorbed from the interface between the liquid and the atmosphere, which is

SEWER FAILURE: The result of acid attack of reinforced concrete, created by hydrogen sulfide gas



NO RESPECTER of materials, sulfides and sulfide gas were responsible for corrosion of steel sewer (left); a pump impeller (center); cast iron pipe (right)

determined principally by the velocity of flow. An exact determination of the marginal flow conditions to provide just enough oxygen to prevent sulfide build-up involved a number of factors. For sewers flowing less than half full a simple approximation relates the required velocity of flow to the B.O.D. and the temperature. This is expressed by

$$(\text{B.O.D.})\ 1.07^{T-20} = 55v^3$$

where T is the Centigrade temperature and v is velocity in feet per second. If the required velocity is attained when the sewer is flowing at, let us say, 20 per cent of the capacity of the full pipe, then satisfactory conditions will also prevail at all higher flows up to 80 per cent of capacity.

In some sewers the flows in the initial years of use may be very small. The velocities under these conditions must be considered if possible sulfide concentrations are to be fully predicted.

The simple equation relating velocity, B.O.D. and temperature has been used as a criterion of design to an increasing extent over a period of 15 years. In no place where the design has been calculated to give the requisite velocities has there been any significant amount of corrosion.

When septic sewage is discharged from a collecting system, an Imhoff tank, or from septic tanks, into an outfall on a steep grade, it should be treated before it goes into the sewer.

It would be desirable to design sewer systems so that there will be a minimum of turbulence at points where force mains discharge into gravity flow lines or manholes.

The sulfate content of the water supply does not determine whether or not there will be hydrogen sulfide generation. Any sewage has enough sulfate in it, even though the water supply has none, so that extremely bad conditions can develop. Experiments on sulfide generation from varying sulfate concentrations invariably show that sulfate concentrations have very little to do with the amount of sulfide generated, with this qualification: sulfide is generated until all of the sulfate is used up; then no more sulfide can be generated.

WHAT HAPPENS to rungs of manhole ladders where sulfide gas attack is heavy

WHAT HAPPENS to cast-iron pipe carrying high sulfide septic sewage for six years

Sulfate attack on concrete which occurs in high alkali soils is not the same as the acid attack in sewers.

The use of Type V cement is not a remedy to the hydrogen sulfide problem.

What to Do About Sulfides

The following are some of the things that might be taken into account in preventing or controlling sulfide build-up.

First, there is the proper design of the system. Considering the factors which cause the generation of hydrogen sulfide—temperature, B.O.D., and velocity or turbulence—the system can be designed to eliminate one or more of the links in the chain of reaction and thus prevent hydrogen sulfide problems. It is sometimes heart-breaking to go to a community and see a system that has been designed with no forethought in respect to the sulfide conditions. It isn't always possible to design to avoid sulfide build-up, but certainly the design should be made with careful consideration of the sulfide problem.

Since one cannot always design so that there will never be any sulfide generation, numerous other things which can be done about sulfides must be kept in mind. One of the most common causes of bad sulfide conditions is long sewer force mains where the sewage is retained out of contact with air. A method which can very commonly be used to decrease, or perhaps entirely eliminate, the generation of sulfides

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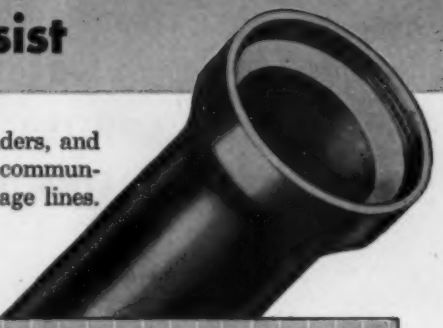

With 1 out of 8 families* now using garbage grinders, and the number increasing steadily, more and more communities are realizing the necessity of Clay Pipe sewage lines.

HERE'S WHY:

INCREASED SULPHIDE ACTIVITY

Many experts claim ground garbage causes an increase in sulphide activity, harmful to most pipe. *Clay Pipe is impervious to sulphides.*

RISING TEMPERATURES

Decomposition of ground garbage particles causes an increase in temperature which has a softening effect on certain types of pipe. *Clay pipe is unaffected by heat.*

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Ground garbage particles tend to pocket in sewer lines, creating acids and gases which corrode most types of pipe. *Clay Pipe is unharmed by corrosives.*

If your community is joining the swing to modern, convenient garbage grinders, be sure to specify and install Clay Pipe sewers! It's the one type of pipe that is unaffected by heat, acids or gases. It's your insurance against future sewer line failures. *It never wears out.*

*American City Magazine Survey

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in a sewer force main is to pump compressed air into it. This cannot always be applied and will not always be effective, but there are many situations where it is completely effective.

After a poorly designed system is constructed, it is up to the maintenance department to see what it can do to relieve the situation. There are a number of things which can be done. Cleaning of the sewers and proper maintenance in general is extremely important. The city of Long Beach, California, which used to have an extremely bad sulfide condition, has licked that completely by a sewer cleaning program.

Cities are finding that they have to give attention to the maintenance of sewers. There have been some law suits in which a city was sued because sewage backed up and flooded a basement. The courts have held that it is not sufficient for the city to say that they didn't know that there was a stoppage. It is the responsibility of the city to inspect and maintain the sewers, because of the fact that that sort of thing can happen.

A program like that requires a good maintenance man and a regular program of cleaning. Some lines are cleaned of slimes every year; some lines may go for two or three years, depending on how much has accumulated. It may be worthwhile in some force mains to run a cleaning ball through the line every few months to aid the hydraulics of the system as well as to prevent sulfide build-up. It is an easy thing to do. If a sewer is cleaned often, it doesn't cost much to clean it.

In some places, the generation of sulfide is controlled by intermittent treatment of the sewer with an agent which will kill and clean out the slimes. The most practical of these is probably lime. A dosage of 6,000 to 10,000 ppm is put into the sewer over a period of about 45 minutes once or twice a week. This will keep sulfide generation down fairly well. Sulfuric acid also has been used. In one place, it has been used in a line intermittently for eight or ten years, principally to eliminate carbonate scale. Once a week a load of sulfuric acid is put into the plant; it also keeps down the sulfide generation to a large degree. The tanks there are made of concrete, incidentally.

Other chemicals that are used at times are chlorine, sodium nitrate, and in some instances metallic salts. Chlorine is rather expensive, but will do the job if used in sufficient amount.

In some places structures are being protected by putting a little ammonia in the atmosphere. The largest installation of this sort is at the sewage treatment plant of the City of Los Angeles. In manholes and some other small structures, protection is obtained by hanging a can of ammonium carbonate with a few holes punched in it. When the ammonium carbonate evaporates, it neutralizes the acidity on the concrete walls and does the job of protecting in this manner. (The ammoniation process is patented but not expensive.)

If ammonium carbonate is supplied at a manhole, the ammonia will drift into the pipe as far as the hydrogen sulfide produced by turbulence at that manhole will drift. How far this will be depends on the slope and the diameter of the pipe.

Other measures that are used are: control of industrial wastes or control of the B.O.D. of the sewage, dilution of the sewage if sufficient water is available, or even the use of industrial wastes which might be used for sulfide control. The particular situation should be studied for the best solution.

(Photos courtesy of Flexible, Inc.)

Whether done by machine power (upper) or hand power (lower), cleaning of sewers is a "must" if hydrogen sulfide formation is involved

Cements, Aggregates and Coatings

Sulfuric acid will react with any cement which depends upon calcium silicates and aluminates for cementation.

Sulfuric acid reacts with the cement in concrete, rather than with the sand or gravel, when ordinary river sand and natural gravel are used. The factors which govern these reactions with concrete affect the cement in cement-asbestos pipe the same way. Any type of Portland cement will react with sulfuric acid. The rate of penetration may vary, however, because this depends upon the amount of material present to react with the acid. Concrete with sand and aggregates which will react with acid will deteriorate more slowly than concrete in which only the cement is reactive.

One thing which might be done where strong acids are present in a sewer is to increase the wall thickness of the pipe. This means adding

an extra inch or so to the wall of the pipe, and placing the inside cage of steel one inch farther back from the inside surface of the pipe. In most sewers it will take 100 years for sulfide attack to penetrate an inch of concrete. It is reasonable to allow such corrosion. It is done in other structures, such as cast iron, where some corrosion is expected under certain conditions and allowance is made for it. It must be understood, however, that this suggestion of extra thickness is only meant for cases where sulfide prospects have been evaluated and where it is shown that the extra thickness is necessary and adequate.

There is in existence a sewer where the concrete has suffered badly, but where acid-proof brick and acid-proof cement in the manholes has stood up for at least twelve years with virtually no deterioration. In some other places acid-proof cement has been used as a pointing for mortar between bricks to a depth of about an inch, but the acid diffuses through to the cement behind and pushes the acid-proof cement pointing right out.

A lot of thought has been given to protecting the surface of concrete with coatings of various sorts. The use of vitrified clay liner plates to protect the inside of concrete sewers was thought to have great possibilities. Installations of this kind were made in Los Angeles in the 1920's and 1930's. After three or four years many of the liner plates fell off. Some of them were split or otherwise damaged. It was concluded that sulfuric acid formed on the walls of the sewers and simply permeated through the liners and attacked the concrete behind them.

It was then thought that by putting a ceramic glaze on the clay the problem might be solved. The author recently made an inspection of six miles of sewer which was built twelve years ago. About ⅓ of the plates were off or damaged to some extent. It was found that these plates, while superior to earlier ones, still had some porosity. Some of them had become cracked and in some places the jointing was imperfect. The clay pipe companies are still working on the problem of producing a sufficiently impermiable lining, and have made considerable progress.

As to painted, sprayed or spun coatings on pipe, there are many different kinds that might be put on. In the water works field, the best coating for the inside of a steel pipeline seems to be a very carefully applied coal tar enamel. In sewage, if there is no sulfide involved it probably would stand up about as well as it would in a water main, which might be for a considerable number of years. If there is acid present, the resistance of such a coating would be doubtful.

The trouble is that if one of those protective coatings is put on it has to be practically perfect in order to serve its purpose. If there is the tiniest flaw somewhere, the acid which cannot react on the surrounding surfaces will tend to get into that flaw and will eat in particularly fast.

As to whether flaws would develop in a coal tar coating due to flexing of the pipe—that depends on the coal tar. There is the possibility of flaws developing from mechanical damage or imperfections. If there are such flaws, the pipe would suffer damage from sulfuric acid with deeper penetration than it would in the absence of any coating at all.

If a coating is to be put on either concrete or steel, the engineer must be sure that it is going to last. The possible resistance of coal tar enamel to long immersion in sulfuric acid is not adequately known. Sewers must last for a very long time. Repair or replacement of a coating cannot be done very easily. It can be done more easily in a water main where, usually, the water can be shut off for a while. Sewage just keeps on coming every day. Coal tar enamel may be used, but it should be only after careful investigation of whether it will permanently protect the pipe against, say, 10 per cent sulfuric acid, and what the prospects will be of repairing it if any flaws do develop.

Asphalt base coatings cannot be expected to be effective. Water can permeate asphalt. If the water is very corrosive, it may be only a few months until an asphalt lining on pipe loosens and comes off in big sheets. The author recently tested the asphalt in one such case. It showed 15 per cent of water in the asphalt, even with the surface wiped dry. Let the asphalt dry out for a while and the water is gone. Soak it in water and it takes up the water again. The City of Los Angeles, in some tests, has reported that asphalt has taken up water until it reaches about 37 per cent of the weight of the asphalt.

If water can diffuse through asphalt, sulfuric acid can too. For that reason, one cannot expect asphalt to provide any satisfactory degree of protection for metal or concrete against the attack of strong acids. Experience has shown that it cannot serve that purpose.

Small-Diameter Concrete Pipe for Sewers

Some engineers have for many years specified large-diameter concrete pipe for sanitary sewers, but are reluctant to specify it in the smaller sizes.

Sanitary engineers use concrete pipe in the large sizes anyway. In the Los Angeles County Sanitation Districts, which constitute a wholesale collection and disposal agency, and whose sewers go down to about 12 inches in size, concrete pipe has been put in for several years and they are having no difficulty.

In sizes smaller than 12 inches the economic advantage of concrete pipe is not so great as in the larger sizes. There is a disposition on the part of some engineers to make blanket rulings against concrete pipe in such sizes. In some cities or in parts of some cities there are places where there is too much uncertainty about possible future service conditions to make it practical to distinguish between the sewers which should be made of concrete and those which should be made of clay, but large scale banning of concrete pipe, even in small sizes, may do a great injustice to concrete pipe as well as to the taxpayers who must pay the cost. Thus, in one city there are a series of lines running down a sloping terrain at slopes of 1 per cent or more. Some of these are of concrete and they show no deterioration after 25 years. There are other parts of the city where flat grades and other adverse conditions caused sulfide generation. It would be unfair and uneconomical for a city of this sort to make a blanket ruling which would prevent the use of concrete pipe on the good slopes just because concrete pipe under some other conditions may suffer corrosion.

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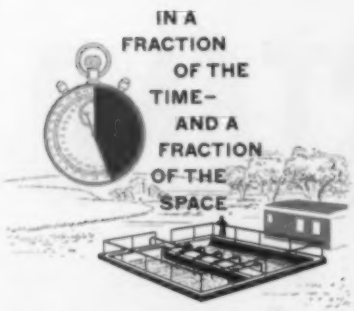

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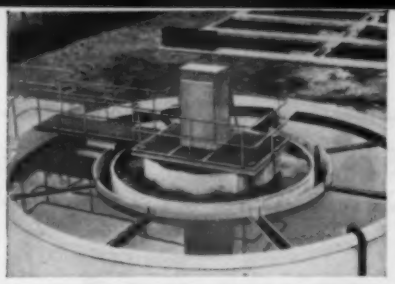

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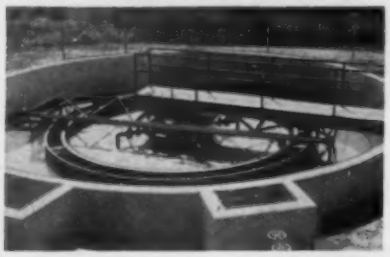

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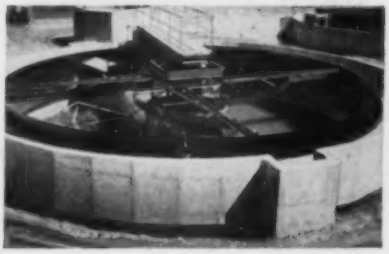

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Sedimentation Units

by FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

SEDIMENTATION tanks have been designed in both rectangular and circular shape. Proponents of each design have their arguments and it is not the purpose of this article to comment on the merits of either.

Rectangular Tanks

Equipment of this type is in a highly competitive field. For fair competition and in order to obtain the best equipment available with reasonable assurance of satisfactory operation and long life, it is desirable to specify the equipment in considerable detail. Manufacturers of this type of equipment include Chain Belt Co., Jeffrey Manufacturing Co., Link Belt Co., and Walker Process Equipment Co.

Chain and Flight Construction

Mechanisms include chains, flights, sprockets, shafts, and drive unit. The chains should be rugged and durable. Specifications commonly require that the chains be for the pintle type and made of processed malleable iron such as "Supermal," "Promal" or "Z-metal" with an ultimate tensile strength of not less than 70,000 psi. (pounds per square inch). The required working strength of the chain can be readily determined by consultation with the manufacturers and should be included in the specification so that all will quote on the same basis. Chains have been supplied with copper-bearing riveted steel pins. There is evidence that these pins wear and produce excessive elongation resulting in wear on the sprockets. Recently some of the manufacturers have recommended that the pins be of hardened steel.

Attachments for the chains to the flights at one time were commonly designed for bolting to part depth of the flight. There has accumulated some evidence of the flights splitting, under this condition, longitudinally beyond the attachments. Some manufacturers recommend a full depth flight attachment in order to strengthen the flights against this splitting. Because of the competitive situation, it is necessary to specify the full depth attachment if it is desired.

Flights are commonly specified to be of redwood. For the smaller tanks, sizes of 1⅝ by 5⅝ in. dressed, are suitable. For some of the larger tanks sizes of 2⅝ by 7⅝ in. dressed, appear advisable. The flights ride on rails embedded in the bottom of the tank for the collection of sludge and upon angles supported from the sides of the tank for the return flight. Wearing shoes are provided on the flights. Johnson[1] reported that replacement of these wearing shoes caused excessive labor and expense and recommended removable wearing shoes as illustrated in Fig. 1 of his paper. We have adopted this as standard construction and our specifications require that "The flights shall be provided with chilled cast-iron wearing shoes inserted into malleable-iron holders bolted to the flights at points of contact with rails in the tank bottom and with supporting angles." The castings must be of such workmanship that the removable shoe will not shake loose during ordinary operation of the flights.

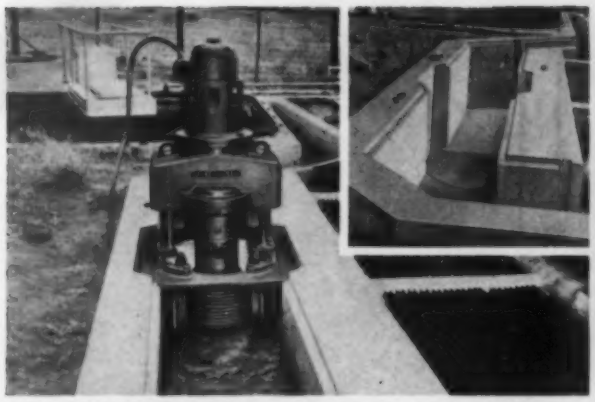
At the Minneapolis-St. Paul sewage treatment plant as reported to the writer by Kerwin L. Mick, Chief Engineer and Superintendent of the plant, the best answer to the shoe-wear problem, under the conditions at that plant, is the application by welding of two "Stellite" strips about ⅜ in. wide and about 2 to 2½ in. apart on each shoe. He reports that the wear on the bottom rails set in the concrete is not excessive and when it does occur, the situation is easily remedied by spot welding flat steel strips on top of the original rail. Some of such work was required in 1947 after seven years of operation with the "Stellite" strips.

Material improvements have been made in the sprockets. The "hunting tooth" or "extended life" sprockets are claimed to reduce wear on sprockets by about 50 per cent. Several of the manufacturers have agreed that it is desirable to specify sprockets of alloy cast iron with a nickel content of 1.00 to 1.25 per cent and a chromium content of 0.45 to 0.65 per cent. The sprockets should be chilled to give them a hardened tooth surface.

Recently a survey was made of chain-and-flight type sludge collectors in primary sedimentation tanks at 10 sewage treatment plants in New England with from 9 to 16 years' operating experience. There were 49 individual longitudinal collectors operating on the average for 11 years. The aggregate experience in repairs and replacements for all of this equipment is as follows:

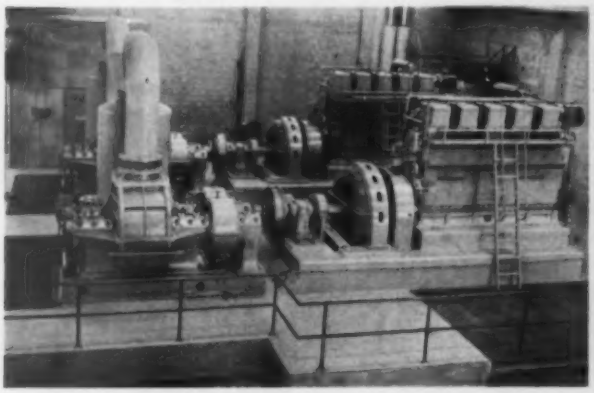
Drive chains, replaced in 2 tanks after 10 years of operation, a few links and pins replaced in 7 tanks.
Drive sprockets; 2 replaced.
Idler and take-up sprockets; 1 replaced, 1 redrilled.
Main chains; 1 broken link.
Flights; total of 20 replaced at 9 plants, replaced as broken at tenth plant with no record.

Toledo, Ohio—Link-Belt Straight Line Collectors

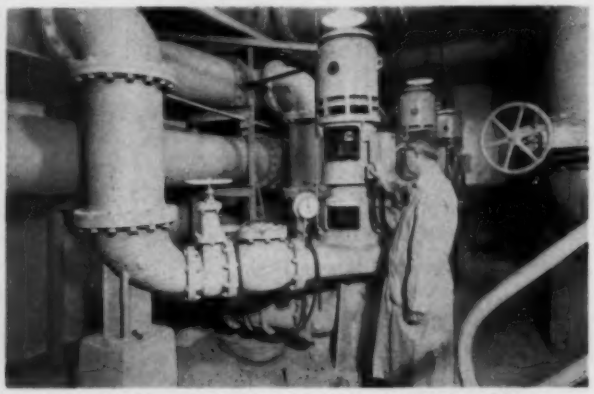


COMMINUTORS. Since raw sewage flows straight through in the Worthington design, the comminutor can be installed in a simple rectangular channel (inset) without expensive masonry work. This one is located at Klamath Falls, Ore.

MIXFLO PUMPS. Available in sizes from 2 MGD to over 300 MGD, Mixflo pumps have non-clogging sewage-type impellers for passing large solids. This one handles raw sewage in the new Salem, Ore., Treatment Plant.



DUAL-FUEL ENGINES. Operating on oil or gas or any combination of both, these Worthington dual-fuel engines drive blowers for the Little Ferry, N. J., Treatment Plant of Bergen County Sewer Authority.



FREFLO PUMPS Available in sizes from 100 GPM to 5 MGD, these Worthington Freflo pumps in the Bethlehem, Pa., Sewage Disposal Plant offer maximum freedom from clogging.

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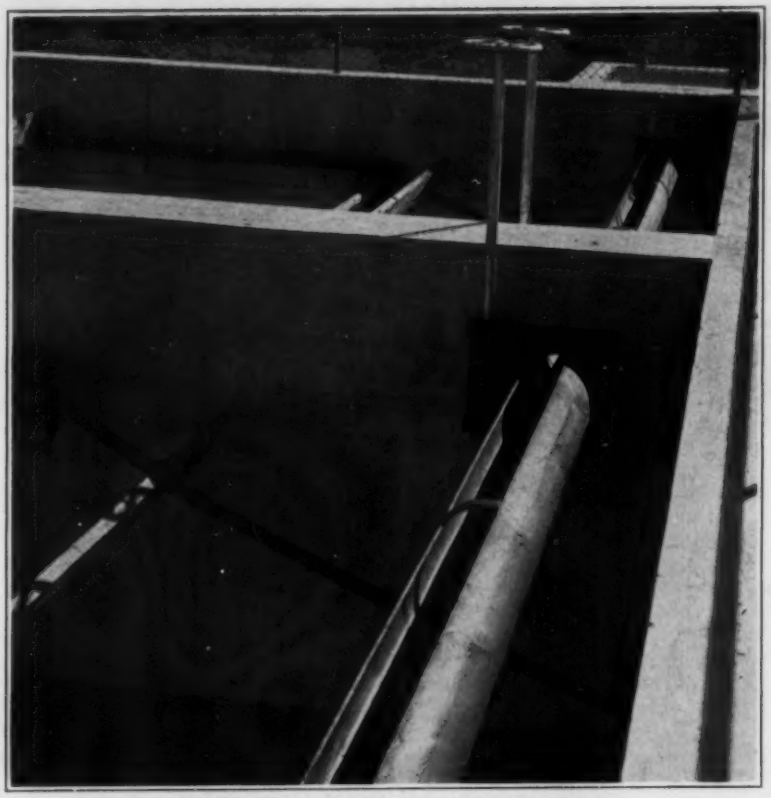


Bristol, Conn.—Skimming pipes for scum removal

Flight shoes; no replacement at 7 plants, replaced after 11 years at 1 plant, replaced every 3 years at 1 plant and 12 individual replacements in 16 years at 1 plant.

Omitting one plant which operates the equipment continuously 24 hr. per day, the indicated life of the various parts, as reported by the operators, is 10 to 21 years for drive chains, 14 to 26 years for drive sprockets, idlers and take-up sprockets, 13 to 24 years for main chains, 10 to 26 years for flights, and 3 to 19 years for flight shoes.

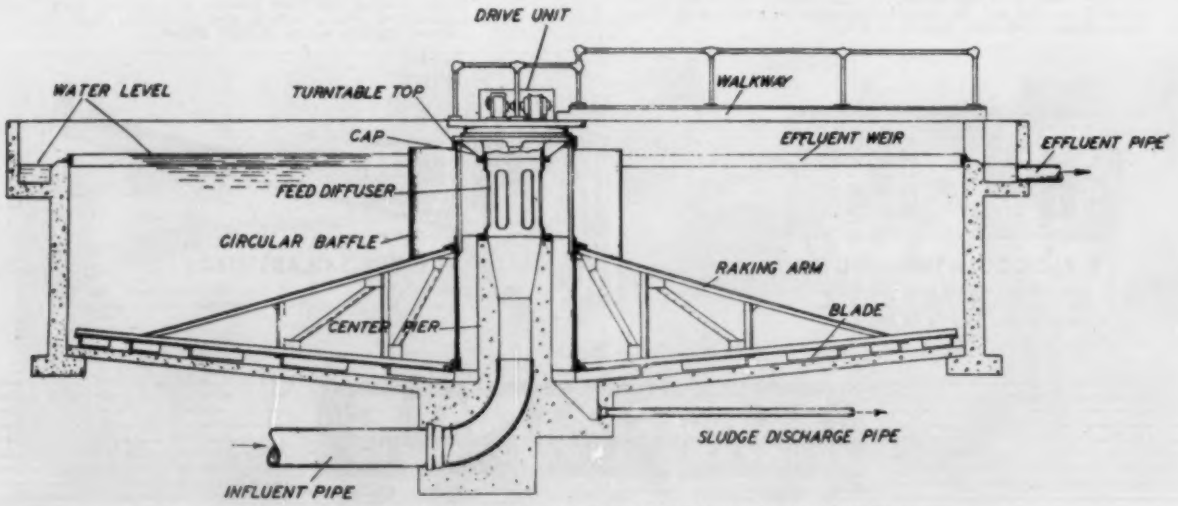
Mick of Minneapolis-St. Paul San. Dist., reports to the writer that all of the original main sludge collector chains in the Minneapolis-St. Paul sewage treatment plant sedimentation tanks placed in operation in 1938 are still in use. On two of the tanks, the chain would soon be worn through the barrel but it is planned to turn this chain over before that happens. The wear will then come on the other side of the barrel and it is expected that the life of the chain will be prolonged several years thereby.

Experience has disclosed that the life of the equipment may be prolonged and the cost of renewals and repairs reduced by operating the equipment in primary settling tanks for a few hours each day during sludge withdrawal operations. In small plants, chains and shoes which may require replacement at the end of 10 years for equipment operating 24 hours per day should last from 15 to 20 years if operated 1 to 3 hr. per day. For the largest plants more frequent replacement may be required.

Chain-and-flight construction is particularly adapted to covered sedimentation tanks as at Detroit, Boston Nut Island, Toronto Ashbridges' Bay Los Angeles Hyperion primary settling tanks, among the larger plants; and Greenwich, Connecticut; Tonawanda, New York; Greenfield, Massachusetts; and Warren Rhode Island, among the smaller plants. This type of construction is also advantageous for rectangular tanks in which it is desirable to remove the sludge rapidly and continuously so as to avoid deterioration in its quality.

Overload Release

The most common method of providing against damage to the equipment because of overload is by shear pins. However, if a shear pin breaks because of overload the temptation is strong to put in a stronger pin and attempt to get the equipment moving rather than to unwater the tank and find out the cause of the overload.



Cleveland, Ohio—Design of Dorr Center Drive Sifeed Circular Clarifiers

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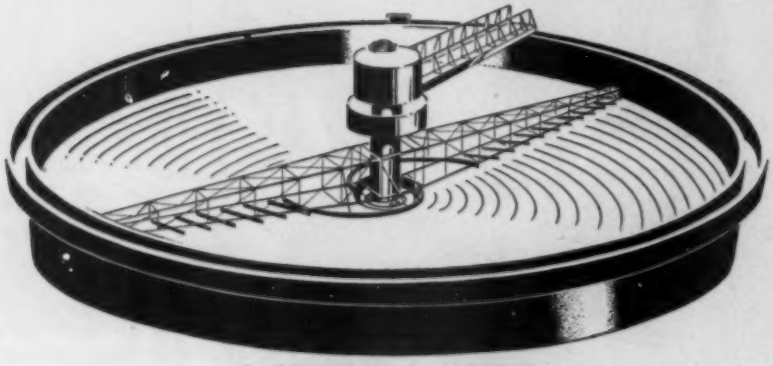
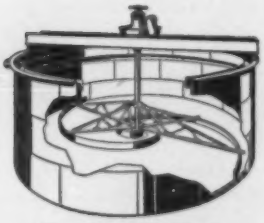


• CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge. Bulletin 35-D-15.



• THICKENERS

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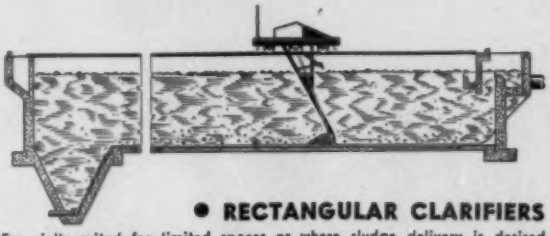
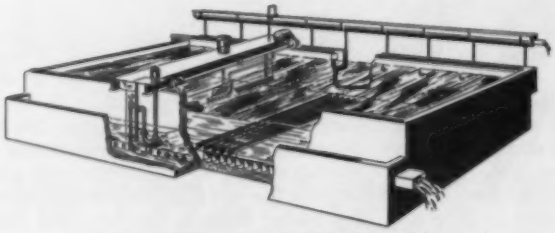


• RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top. Bulletin 35-D-15.



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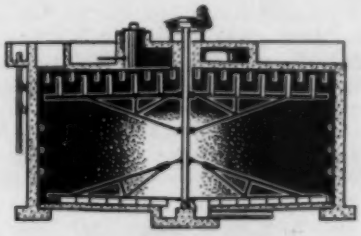
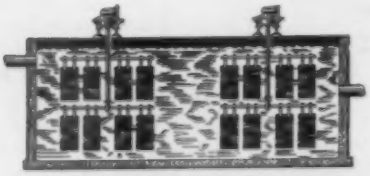


• DIGESTERS

Sludge scrapers and scum breaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-D-15.



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Topeka, Kan.—Chain Belt Tow-Bro Sludge Removers

Major damage to equipment has been caused by the substitution or use of improper shear pins.

Several adjustable overload release devices have been developed to mechanically disengage the collector from the motor when overloads are encountered.

The Chicago Sanitary District is well satisfied with the operation of individual motorized reducers on sludge collectors. The basis of this design has also been described by Johnson.[1] All parts except the flights are designed to withstand the torque of the motor. Consideration must be given to the motor size and to selecting characteristics such that the maximum torque is not materially greater than the running torque. Particular attention should be given to possible deflection of shafts and consequent effect on bearing mountings. Self-aligning bearings are helpful to prevent difficulties of the latter type.

It appears advisable to specify that bolts shall not be less than ½ in. diameter and structural steel shapes shall have a thickness of not less than ⅜ in.

Sludge Hoppers

Multiple hoppers for collection of sludge at the ends of rectangular tanks have caused operating headaches as the sludge tends to collect and hang up on the sides and in the corners. In time, this sludge becomes gas lifted and belches to the surface. The operator afflicted with this type of tank must spend considerable time pushing the sludge down to the bottom of the hoppers where it can be picked up by the pump suction. Even in relatively narrow tanks it appears advisable to provide cross collectors so that insofar as is practical, sludge is brought to the drawoff piping mechanically. In small tanks where longitudinal chain and flights have been used to collect the sludge at the ends of the tanks, it has in some instances proven practical to install cross collectors of the spiral conveyor type.

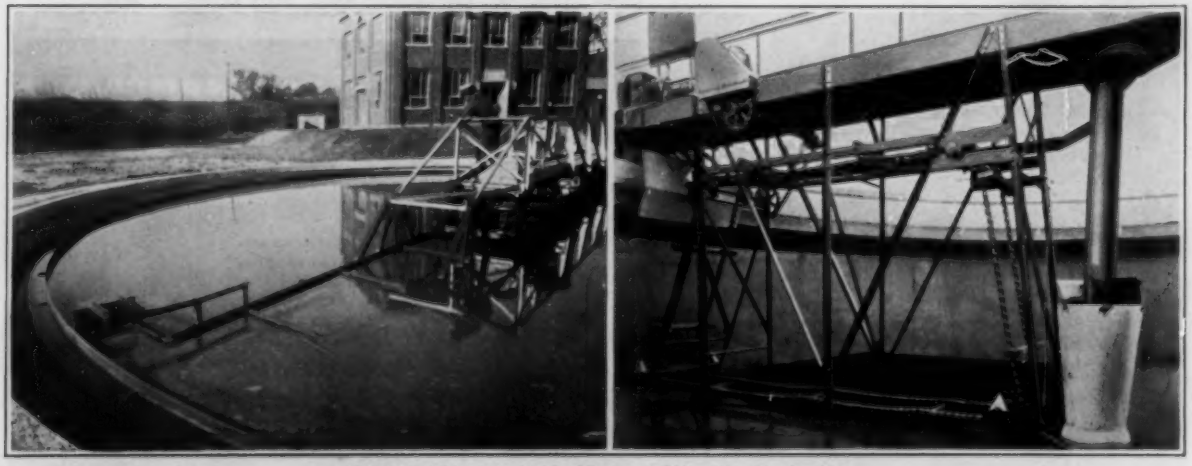
Scum Removal

Various types of mechanisms have been devised for withdrawal of scum from rectangular tanks equipped with chains and flights for sludge and scum collection. The rotated slotted pipe provides a simple means for manual control of scum withdrawal. (See accompanying cut for Bristol, Conn.) Where such manual control is too laborious it is possible to use mechanical means. One of the simplest mechanical skimmers consists of a rotating spiral squeegee which carries skimmings up a launder and discharges them into a scum trough, whence they are transmitted by water carriage to the disposal facilities. This type has been provided for the Los Angeles Hyperion primary settling tanks.

At the Boston Nut Island plant provision is made for conveying the scum while still floating on the sewage to one scum storage sump for each of two large rectangular tanks. The equipment is of the chain-and-flight type.

Crane-and-Bridge Type

Prior to 1939, the policy of the Dorr Co. was to recommend circular clarifiers wherever possible. As competition developed for their equipment in the circular tank field and as rectangular tanks with common walls were often preferred by some engineers under certain circumstances, the Dorr Co. developed and advocated the Monorake for sewage sludge removal from rectangular sedimentation tanks. This equipment was originally developed by them primarily to meet the need for mechanical removal of sludge from sedimentation tanks following



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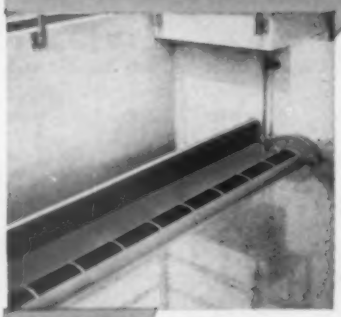

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Continuous research, product development and improvement have long been guiding principles of CHAIN Belt Company. The important developments illustrated above are but a few of the contributions CHAIN Belt has made to more efficient plant performance . . . a quarter century of sanitation progress. Such mechanical features as Z-Metal chains, self-aligning bearings, centralized wearing shoes, split head-shaft sprockets have meant much in longer life, lower operating and maintenance costs and better operation to plant operators the world over.

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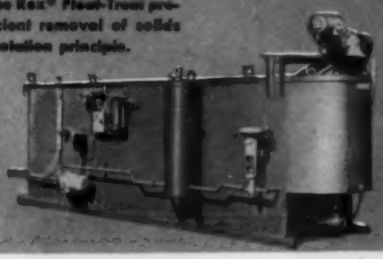

"flocculators" in water treatment plants. The Monorake type of sludge removal equipment is reported to be available for rectangular sedimentation tanks up to 60 ft. wide and any reasonable length. This type of equipment includes a balanced raking mechanism supported and operated from a carriage spanning the width of the tank and traveling on longitudinal rails. The carriage is operated by cables. The rakes are so set as to collect the sludge in one or more hoppers at the influent end of the tanks. The first large installation of this type was at the Coney Island plant in New York about eight years ago. The principal difficulty encountered has been with failure of the reversing switch to operate. It is understood that the manufacturer has improved the design in this respect. The average life of the cables at this plant is said to be about five years. Other items of equipment requiring occasional replacement are cable sheaves, flight shoes, carriage wheels, and bearings.

One of main advantages of this type of mechanism is that the amount of equipment immersed in the sewage is reduced to a minimum and all equipment can be raised above the sewage level for renewals and repairs. Thus it is not necessary to unwater the tank for such work.

The Hardinge Co., Inc., makes sludge removal equipment for rectangular tanks consisting of a bridge crane which spans the width of the tank and supports the sludge scraper and skimmer. The sludge is collected in one or more hoppers at the influent end of the tank or in a trough equipped with a cross screw sludge conveyor.

Circular Tanks

The Dorr Co. has been the outstanding manufacturer of sludge removal mechanisms for circular sedimentation tanks. Also in this field are Hardinge Co., Yeomans Brothers Co., Infilco, Inc., and Chain Belt Co.

In the Dorr Type S clarifier, feed is introduced through a centrally located, inverted siphon with the inlet surrounded by a submerged diffuser. From the center inlet, the sewage flows radially to a peripheral weir. A motor-driven revolving rake sweeps the settled solids to a central discharge hopper in the tank bottom. Representative installations include the primary settling tank at the District of Columbia and the final settling tanks at the Cleveland Easterly plant. L. M. Johnson[1] has described the advantages gained by the use of stalling torque motors to drive equipment of this type at the plants in the Chicago Sanitary District. The clarifiers in the 126-ft. diameter final settling tanks at the Chicago Southwest plant are driven by ½-hp. motors through 69,500 to 1 combination helical and spur-gear speed reducers. The motor constitutes the only protective device throughout the entire gear train.

Tanks of this type afford only a small hopper for sludge accumulation. For the Dorr clarifier at the Terminal Island plant in Los Angeles, the operators report that it is desirable to provide automatic programmed intermittent operation of the raw sludge pumps in order to withdraw reasonably well concentrated sludge.

In very large circular final settling tanks, wind currents and high rates of weir discharge for a single peripheral weir have been reported to induce the discharge of unduly large quantities of suspended solids with the tank effluent. The unit weir discharge rates may be substantially reduced by the provision of supplementary weir capacity in connection with an effluent trough built within the tank and supported from the outside wall.

There is evidence to show that, on the average, the cost of maintenance, renewals, and repairs on sludge removal equipment in circular tanks is relatively low.

The sludge withdrawal pipelines from circular tanks are of necessity longer than for rectangular tanks. There is very little evidence to show that this has caused unusual operating difficulties except at the Buffalo plant. Here the sludge withdrawal lines became plugged with grit and heavy sludge to a serious extent as reported by John W. Johnson.[2]

Various devices have been developed for collection of scum on the surface of circular primary sedimentation tanks. The collection is sometimes effected by wind currents. Several instances have been observed where the operators have improved upon the standard form of scum collector supplied by the manufacturer but the improvements have not been described in the technical literature.

References

1 L. M. Johnson, Mun. Sanit., Nov. 1938, p. 529.
2 J. W. Johnson, Sew. Wks. Engr., Aug. 1944, p. 386.

"from Chicago"

greater flexibility in comminution*

for sewage flows from .005 to 250 mgd per machine installed in a 6 in. pipe, a basin, or a rectangular channel section.

The greater flexibility and wide applicability of comminution made possible by the equipment illustrated here is the result of Chicago Pump Company's original development of comminution and the Chicago Comminutor and its 20 years of experience in over 4000 installations of exclusively successful comminution.

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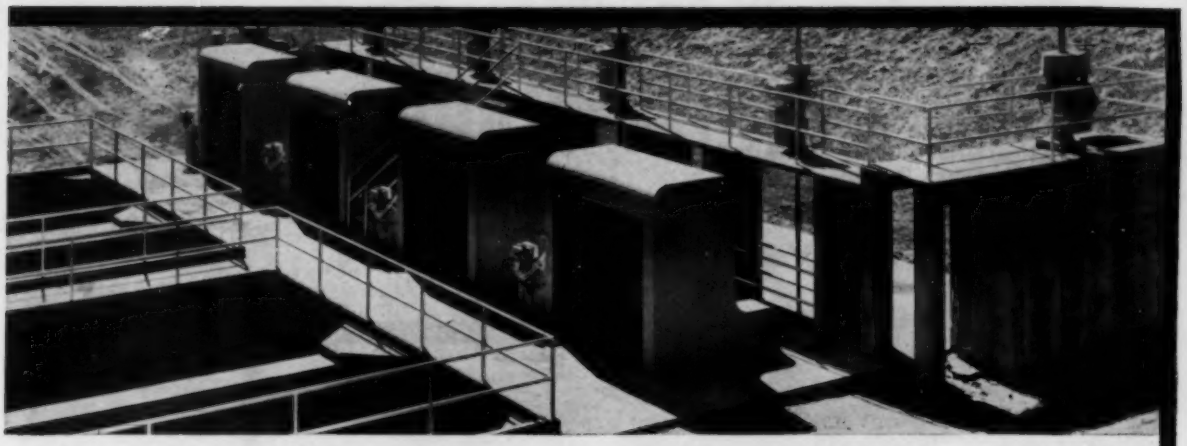
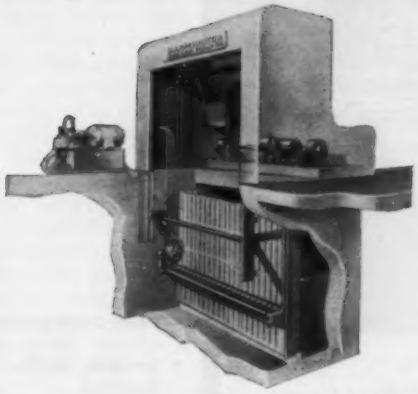
*Continuous screening and subsurface cutting of coarse sewage material without removal from the sewage flow, eliminating unsightliness, nuisance and odor from screenings.

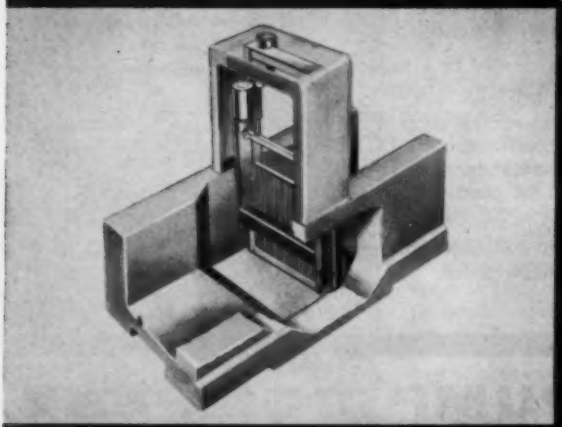


The illustration shows the primary grit channels, four BARMINUTOR® comminuting machines and motorized gates at the Indianapolis, Indiana sewage treatment plant. Design of plant by Moore and Heger, Consulting Engineers, Indianapolis; constructed by H. D. Tousley Company, Inc., Indianapolis, for the Indianapolis Sanitary District, Mr. Dwight O. Bender, Superintendent.

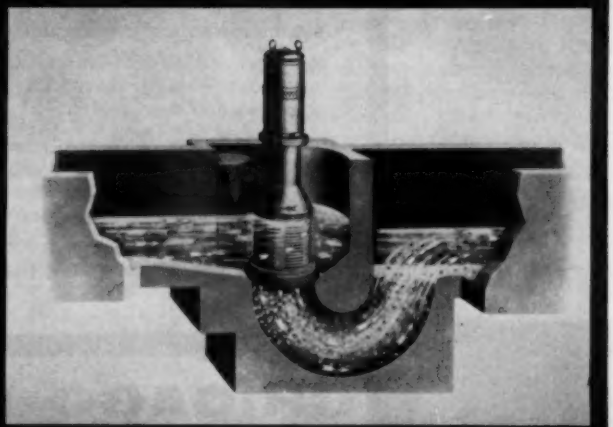


Model "A" BARMINUTOR® screening and comminuting machine. Designed for use in rectangular channel sections 4 to 12 feet wide, sized for flows of 10 MGD and upwards.

Chicago 7B Comminutor designed for use in 6" or 8" sewer pipe, sized for flows from .005 to .175 MGD per machine.



Model "B" BARMINUTOR® screening and comminuting machine. Designed for use in rectangular channel section 1 to 3 feet wide, sized for flows from .09 to 15 MGD.



Chicago Comminutor, designed for use in hydraulically designed feeder basin, sized for flows from .175 to 25 MGD per machine.

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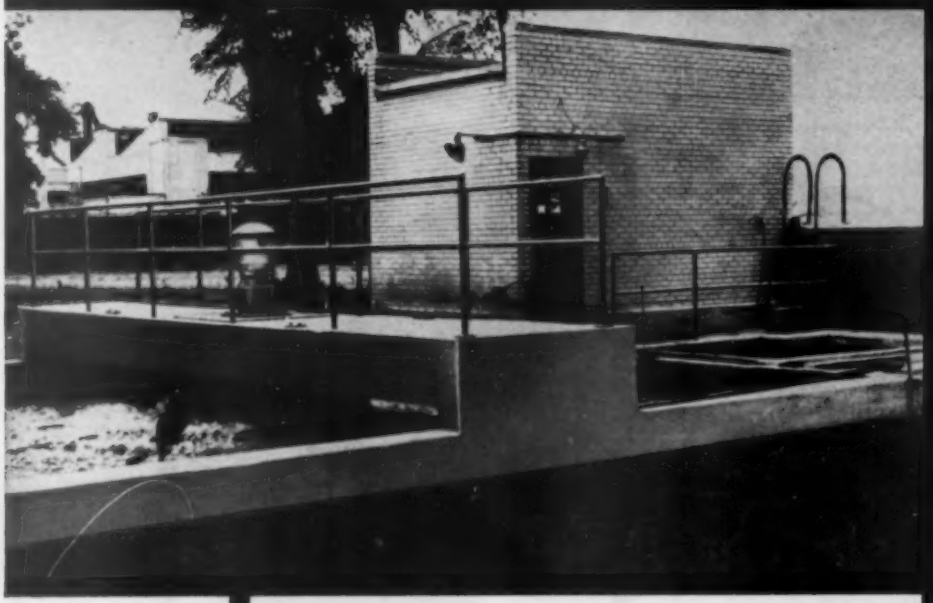
AERATOR-CLARIFIER UNITS

for Small, Compact Activated Sludge Plants...



Aerator - Clarifier unit serving as sewage treatment plant for the Goodyear Tire and Rubber Company of Topeka, Kansas.

Aerator-Clarifier units have a proven 21 year record for producing sparkling clear effluent.

Many semi-automatic features of the combination Aerator-Clarifier unit simplify operation and insure trouble free performance under all conditions. These combination units can be operated by men with State Board of Health minimum classifications.

Aeration and clarification are accomplished in a single tank with positive sludge control that covers a wide range of sewage flows and strengths.

Aerator-Clarifier units handle sewage flows from 15,000 to 500,000 gallons per day in single or multiple units. They may be safely located near dwellings as the plants are free from flies, odors, and unsightly appearance.

Specify Aerator-Clarifier units for small activated sludge plants to assure proven and trouble free performance.

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Pumping Grit and Sludge*

by PAUL M. THAYER

District Manager, Chicago Pump Company, Milwaukee, Wis.

IN ANY DISCUSSION of pumps, consideration must be given to all conditions of the installation. The correct pump improperly located or with improper piping cannot operate successfully.

Somewhat similar pumping problems must be considered when pumping either grit or sludge since both materials have a relatively high solids content and may be quite abrasive.

Grit Pumps

Many grit tanks are equipped with mechanisms that rake or convey the grit from the grit tank to an elevated point of discharge where it can be dumped into a truck, wheelbarrow, or other conveyance. These tanks do not require a pump for handling grit regularly, but they may require a pump for dewatering purposes. For such service a standard non-clog pump should prove adequate. Occasionally the grit tanks are designed or located so that mechanical devices will not remove the grit and other methods must be employed. In large treatment plants, particularly where a high lift is required, the use of a clam-shell bucket (Figure 1) with a traveling crane or a jib crane appears to give the most satisfactory service.

FIG. 1.—GRIT removal with clam shell bucket.

Air Lift

A simple device that is satisfactory for grit pumping in many of the smaller installations is the air lift. The discharge pipe should be not less than 3 in. in diameter, and there should not be any restriction in the piping. The submergence, the lift above the water surface, and the air volume and pressure must all be properly proportioned to produce a minimum velocity of 3 ft. per second. In those cases involving a lift greater than the submergence of the air lift, a two-stage air lift can be used.

Water Jets

Water jets have also been used for removing grit from grit tanks. Unfortunately these units usually have been unsatisfactory, primarily because of the nature of the water jet itself. To impart a satisfactory velocity to the water it is necessary to utilize the nozzle principle, which is a restriction in the throat of the eductor pipe. This restriction causes frequent plugging of the jet by the large particles that usually are present in grit.

Other Units

Centrifugal or plunger pumps should not be used regularly for handling grit. As an emergency operation or for dewatering grit tanks, any standard type of sewage pump that has the proper capacity and head characteristics will do; but for routine operation some other method of removing the grit must be utilized.

Sludge Pumps

Sludge pumps can be classified according to the service performed. The principal services are:

1. Pumping primary settled sludge to the digester.
2. Pumping secondary settled sludge to the aeration tank in an activated sludge plant.
3. Pumping waste activated sludge to the primary tank.
4. Pumping digester sludge to sludge drying beds or to vacuum filters. Recirculation of digester contents for mixing or heating in an external sludge heater also come under this classification.
5. Pumping the sludge from humus tank (secondary clarifier) to the primary tank or digester.

Frequently one pump may be required to perform more than one type of service, and it must have the proper characteristics for each service. Of the foregoing types of service, that of handling raw or primary sludge presents the most difficult problems. Raw sludge, by its very nature, always contains much solid and other foreign material; also, its consistency varies widely from treatment plant to treatment plant and even from hour to hour in any particular plant. The solids concentration may vary from a minimum of 2 per cent to a maximum of 14 per cent. Both the pumping head and the discharge rate may vary widely, due to operating considerations.

Plunger Pumps

The particular application in the sewage treatment plant would dictate whether centrifugal or plunger type sludge pumps should be used. Plunger pumps always should be used where a suction lift is required with a moderately high total pumping head. They should never be used where there is a high suction head and a fairly low total head. If either the suction line or discharge line is long, air chambers should be installed to cushion the hydraulic shock. Provision is usually made for varying the plunger pump capacity by varying either the speed of the motor or the piston stroke, or both.

Plunger type pumps have the following advantages:

1. Satisfactory operation with a suction lift.
2. Pump at low rates.
3. Deliver a constant volume at varying heads.

Conversely the disadvantages are:

1. Both messy and noisy to operate and maintain.
2. Has small capacity and large space requirements.
3. High maintenance cost.

Centrifugal Pumps

Centrifugal pumps should be used for raw sludge pumping only when there is a positive suction head. The suction line should be as short as possible with a minimum of fittings. Ordinary non-clog centrifugal pumps are occasionally used for sludge pumping; however, considerable clogging is experienced due to rags and debris becoming entangled with the impeller. There are specially designed centrifugal pumps, such as the "Scru-Peller" pump (Figure 2), that incorporate special cutting devices to cut up rags or ordinary debris that enter the pump housing.

Variable Drive

It is important that a pump handling raw sludge be equipped to vary the capacity while still being able to pump against a great differential of head. This can be accomplished best by a variable motor drive. A variable drive with a constant speed motor may be used or the motor speed may be varied.

The proper control and return of activated sludge is one of the most important functions in the operation of an activated sludge treatment plant. The withdrawal of sludge from each hopper of the final settling tanks should be indivdually and visually controllable. Pumps for this purpose should be capable of operating at various capacities. Heavy duty, horizontal non-clog pumps, equipped with vari-drive motors, are best suited for this service. They should have water seals to prevent sludge working into the packing glands.

Digester sludge generally is similar to activated sludge, so that heavy duty, non-clog pumps are used. The increased use of external sludge heaters for heating the digester is one of the reasons for the increase in digester sludge pumping in treatment plants of newer design. In this service it has been customary to circulate a constant volume of sludge. Although constant speed pumps usually have been employed, it might be better to use pumps with vari-drives because the friction head is constant, and it is often desirable to vary the sludge flow rate.

Other Pump Considerations

Pumps frequently are installed in digesters for other purposes, such as transferring sludge from one digester to another or to drying beds, vacuum filters, or tank wagons. In any case, the ability to vary the capacity and head independently is an important and worthwhile feature.

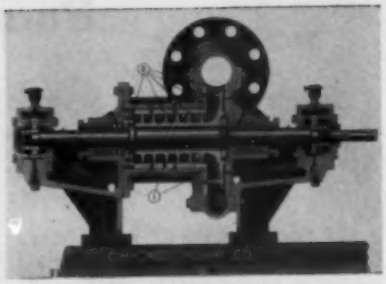

FIG. 2.—SCRU-PELLER sludge pump. 1. Screw and impeller, 2. Cutting edge.

The sludge from the final settling tank is similar to activated sludge. It can be handled by a heavy duty, non-clog pump if there is a suction head. When there is a suction lift or a long suction line, then a plunger pump should be used.

Considerable emphasis has been placed on heavy duty non-clog pumps. These pumps should be designed with ample mechanical strength in shafting, bearings, casings, etc., so that deflection of shafting due to unbalanced loading will not cause undue wear and excessive maintenance.

Raw Sewage Lagoons*

A boon to the small municipality

by GLEN J. HOPKINS and JOE K. NEEL

Sanitary Engineer Director, and Biologist in the Water Supply and Water Pollution Control Program of the U. S. Public Health Service in Kansas City, Mo.

LAGOONS have long been associated with liquid waste disposal. Lagooning is a common process involved in treatment of concentrated industrial wastes, and some lagoons are merely basins in which wastes are stored prior to their treatment or ultimate disposal. They have gained recognition as oxidation ponds for secondary sewage treatment in California and the Southwest; and in the Midwest they have recently demonstrated a capacity for treatment of raw sewage that has resulted in their installation as permanent waste treatment facilities at a large number of small and medium-sized municipalities. Their use in this respect began in 1928 when Fessenden, N. Dak., diked off a portion of a pothole lake to receive its raw sewage discharge. This structure, although not now considered a true lagoon by the State water pollution control agency, has nevertheless functioned rather satisfactorily for 27 years.

History and Status of Lagoons

The merit of this type of sewage treatment gained recognition slowly and no more lagoons were constructed until 1948, when a 10 acre facility was installed to receive raw wastes from about 1,000 people at Maddock, N. Dak. The success of this facility attracted statewide attention and, with the approval of the State Department of Health, lagoons were soon constructed at several other municipalities. Utilization of lagoons then spread to surrounding States, and today their use as raw sewage treatment devices at appropriate locations is regarded favorably by State water pollution control agencies in North Dakota, South Dakota, Montana, Wyoming, Nebraska, Missouri and Colorado. Kansas and Minnesota have used raw sewage lagoons under restricted circumstances. As of January 1, 1956, thirty-eight raw sewage lagoons were in operation in North Dakota; South Dakota had 18, Nebraska 5, Wyoming 5, Montana 15, Kansas 1, Missouri 7, Minnesota 2, and Colorado 9. This totals 100 for the Missouri Basin States. Limited data for each installation are appended hereto. Towns using these facilities vary in population from 150 to more than 10,000. Some units serve the daytime requirements of small numbers of people located at defense installations and public schools.

Although a general feeling now prevails that satisfactory treatment may be realized from introduction of raw sewage directly into a lagoon, a number of older lagoons serve as secondary treatment facilities. Thirty-eight known installations are distributed as follows: Colorado (1), Kansas (18), Missouri (1), Nebraska (4), North Dakota (3), South Dakota (6), and Wyoming (5). Preceding preliminary treatment may include septic tanks, Imhoff tanks, screening, sedimentation, separate sludge digestion, aeration, or chemical precipitation.

Investigations of performance and processes involved in raw sewage lagoons have been rather limited in number. Efficiency of various lagoons has been evaluated by State Health Departments in North Dakota, South Dakota, Montana, and Wyoming. The Public Health Service has cooperated with North Dakota and South Dakota in periodic investigations of lagoon processes. In 1954 a cooperative investigation of an experimental lagoon at Kearney, Nebraska, was initiated by the City of Kearney, the Nebraska State Department of Health, and the Missouri Drainage Basin Office of the U. S. Public Health Service. This study covered a 13-month period of operation and a report will soon be released.

In 1955, the Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, began a comprehensive investigation of a limited number of existing lagoons in the Dakotas. This work is continuing and a progress report of 1955 activities will be released in the near future. No data from that study enter into this presentation.

Design Features

Utilization of lagoons for treatment of raw sewage originated in a sparsely populated region where land values are relatively low and the majority of municipalities are below 1,000 in population. There, lagoons were first regarded as virtual waste detention chambers. Biological activities prevented nuisance development, and evaporation and seepage were relied upon to maintain water below the overflow level and minimize contamination of surface streams. Percolation into the ground rapidly merited consideration as lagoons were generally constructed in tight soils and at locations where they were assumed to have no influence upon ground water supplies.

Investigation of lagoon performance soon demonstrated that they drastically reduced pollution and that overflow or effluent from adequate facilities would cause no degradation of receiving streams. Thereafter curtailment of effluent received less attention and overflow lagoons were permitted where circumstances indicated their desirability. Lagoons of the latter type are becoming more numerous than those designed to afford virtual retention.

Lagoon performance depends upon several features that are largely controlled by design. Adequate circulation and uniform distribution of wastes throughout the contained liquid are required for optimum operation. Circulation may be assured by a location fully exposed to wind action and a depth-area relationship low enough to insure complete mixing.

Optimum depth for a ten acre lagoon seems to be around four feet, but a 20-acre lagoon may function satisfactorily with depths of 7 to 8 feet. Waste distribution is most easily controlled by location of the inlet at or near the center. Side inlets have a tendency to form sludge beds and are generally considered undesirable.

Embankments or dikes should be elevated to minimize entrance of sur-

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* Presented at the 11th Annual Purdue Industrial Waste Conference. Published here by permission.

face runoff, as dilution usually serves no useful purpose. Soil types generally considered most desirable are relatively nonporous mixtures that will permit little infiltration at the start of operations. Very porous soils should be avoided whenever possible as great losses to seepage will slow water rise to an optimum level and hamper development of desirable lagoon processes. Seepage effects upon ground water must be considered if nearby wells exist.

Dikes should be constructed of soils containing considerable percentages of clay or have the water line area shielded against wave action by riprap or other protective measures. Sealing of bottoms progresses with time and fairly porous soils usually become relatively impermeable within a few years. Bottom sealing and resultant decreases in percolation has transformed some retention lagoons into overflow types, and in some cases has necessitated construction of additional lagoons in areas where complete retention is desired.

Economical bottom impermeabilization is a factor of primary importance in extending the use of lagoons into areas of excessive soil porosity. Inexpensive materials such as bentonites and soil blankets offer some promise after limited experimentation; and it appears that their applicability in this respect should be thoroughly explored, as more expensive methods may place lagoons beyond the reach of smaller municipalities.

It is not necessary to consider volume loss from sedimentation in lagoon design, as sludge accumulates in well functioning lagoons at a rate that would require more than a hundred years to produce an appreciable loss of capacity.

The majority of lagoon facilities consist of single chambers which eventually overflow into nearby drainage channels. In some instances raw wastes are discharged into two chambers in a parallel operation, and in a few cases one or more units are operated in series from a primary chamber receiving the raw sewage. The latter type of facility furnishes the greatest degree of wastes reduction but additional purification so afforded is rarely necessary. Added units in a series installation do not reduce the size required for the primary unit.

Capacity now recommended in the Dakotas and Montana is one acre for a four foot lagoon, or four acre-feet per 100 population or equivalent. This recommendation is based upon successful operation of earlier lagoons with such loadings. It assumes that four acre-feet are required to stabilize a daily B.O.D. load of 16 to 20 pounds. To some this loading has appeared too low to realize the maximum potential inherent in lagoon processes. Experiments at Kearney, Neb., where loading at times exceeded 1,000 people per acre, indicated that lagoons would adequately handle a substantially greater load. The State of Missouri was impressed by the Kearney studies and now permits a loading of 400 people per acre. for interim treatment.

Cost Data

Lagoon costs are influenced by the price of land, topography, price of excavation, length of outfall sewers, and other factors. As for other forms of sewage treatment, accurate cost data are usually difficult to obtain. The South Dakota State Department of Health has obtained rather complete cost data on many installations in that State, and this information is available to all interested persons.

For fifteen South Dakota towns varying in population from 367 to 2,871, and averaging 1,102, land costs ranged from $950 to $12,375, averaging $3,558 per installation or $3.23 per capita. Construction costs varied from $4,276 to $31,000, averaging $14,385 per installaton or $13.06 per capita. Total costs were from $5,276 to $42,139, averaging $17,943 per installation or $16.28 per capita. For the three largest communities (2,500 to 3,000 inhabitants), per capita costs averaged $2.78 for land, $10.73 for construction, and $13.51 for the complete facility. For the three smallest communities (below 400 population) per capita prices averaged $1.38 for land, $7.38 for construction, and $8.76 for the complete facility.

Under conditions prevailing in South Dakota, lagoons for very small communities can be provided at a per capita cost comparable to that for communities in the 2,500 range. Virtually complete treatment resulted at lesser per capita cost than is required for conventional primary treatment. Unquestionably, where lagoons can be used successfully, sewage treatment is available at reasonable cost, even for small communities.

Maintenance

Lagoons require maintenance only to the degree of protecting dikes from erosion and animal damage, and controlling certain undesirable aquatic growths. Seeding and fencing are major items in dike protection, although periodic control programs may need be directed at burrowing animals such as crayfish and muskrats. Dikes constructed of light soils may require protection against wave erosion by riprapping or layers of heavy soils at the water line. Aquatic flowering plants and attached algae produce losses in effective capacity and interfere with circulation. While this problem has not been a major one, maintenance should provide for periodic inspection and removal of such growths.

Operational Features

Early successful use of raw sewage lagoons occurred in a region (North Dakota) where they were normally covered with ice for about five months (November to March) each winter. Ice and snow cover and low temperatures restricted biological activities during this period, but ice formed an effective barrier between lagoons and the atmosphere and no nuisances developed. Biological processes, particularly the critical algal growth, developed with the spring thaw and promoted aerobic treatment processes. Thus actual sewage treatment alternated with a static period in which degree of treatment was of little consequence. This condition seems normal for lagoons operating in the Dakotas, Montana, Minnesota, and Wyoming. Overflow lagoons in those areas produce a lower quality effluent during winter months, but its assimilation into receiving streams has posed no problems.

In Nebraska ice cover lasts from about December 1 to March 1. Brief periods of cloudy weather may produce anaerobic conditions of short duration in November and March, particularly with a heavily loaded lagoon, and liberate some odor to the atmosphere. With proper loading, however, odors produced by no means constitute nuisance conditions. At more southerly latitudes (e.g., Missouri) only intermittent ice cover is expected and observed lagoons normally change from aerobic to anerobic status and back several times during the winter. Oxygenless conditions are usually associated with ice cover, and recoveries to aerobic conditions are quite rapid as ice cover disappears. Lagoons in Missouri are discharged to watercourses and winter deterioration in effluent quality is usually not as great as in areas where ice persists two or three months without interruption.

The midwestern States utilizing raw sewage lagoons exhibit wide climatic variation. Average annual precipitation ranges from about 14 to more than 50 inches. Evaporation from shallow lakes and ponds varies from 36 to 59 inches per year, and exceeds annual precipitation over a range of 4 to 31 inches. Average annual temperature varies from 35° to 60°F. The fact that lagoons of essentially similar design have performed

satisfactorily over this wide climatic range argues well for the adaptability of biological processes involved. However, it appears that some modifications in loading, and probably other design criteria, may result in greater efficiency.

Processes Involved

Wastes reduction in lagoons largely represents the cooperative effort of bacteria and algae. Bacteria are mainly involved in breakdown of complex organic compounds to provide a large share of nutrient materials required for algal growth. Algae produce great volumes of oxygen by photosynthesis, the only natural process capable of maintaining an aerobic medium under such conditions. They utilize energy supplied by sewage compounds in their life processes, and incorporate large amounts of energy and sewage materials into their bodies. Organic material contained in lagoon effluents is thus stabilized within the protoplasm of living organisms, and since the majority of these organisms are photosynthetic in nature, the effect of lagoon effluent upon the oxygen content in receiving streams is usually negligible. Algae laden effluents usually increase the oxygen content of receiving waters. B.O.D. measurements of such effluents offer an unreal estimate of their nature, as algae usually deplete oxygen in sample bottles incubated in an environment quite dissimilar to natural conditions.

Algae, usually uninvolved in conventional sewage treatment, are a very important group of organisms in typical lagoon activities. At Kearney, Neb., greatest waste removal was effected when they were most numerous and the least purification occurred when they were sparse or lacking. Algae offer a means of direct utilization of solar energy for waste reduction. Results at Kearney, Neb. indicate that algal growth, at least in heavily loaded lagoons, is largely controlled during open water seasons by variation in available solar radiation. Plankton algae are much more effective than attached or floating forms. Zooplankters and other animals usually occur and often perform a useful service in keeping algae and bacterial densities below saturation levels.

Lagoon cells operating in series afford greater reduction than single chamber units by virtue of the following sequence of events. As indicated above, sewage materials and energy discharged from the first cell are largely tied up in the bodies of a profuse growth of microorganisms. Water in the second cell, largely effluent from the first chamber, has the potential to produce only a fraction of the concentration of organisms attained in the primary unit.

Density of organisms in the effluent from the first cell naturally exceeds this capacity and they are unable to maintain a vigorous growth and therefore die off in the second chamber. They and their detritus are consumed by zooplankters, and large amounts of energy brought to the second chamber are utilized in animal life processes. Thus there is a marked decline in energy level from primary to secondary cells, and effluent from the secondary cell contains only a small portion of the energy and matter it received in organisms contributed from the primary chamber. Energy level is further reduced in a third cell, but very few situations justify treatment to this degree.

Performance

Single chamber lagoons normally afford a degree of treatment comparable to that attained with very efficient conventional secondary treatment. During adverse weather conditions percentage waste removal may decline to the conventional primary level. At Kearney, Neb., for example, where lagoon loadings were frequently more than 10 times as great as practiced in the Dakotas, B.O.D. reduction varied from 32 to 90 per cent with the lower figure representative of winter conditions. During favorable seasons 90 per cent removal was effected with a loading of more than 1,000 people per acre. Maximum loading was 217 lb B.O.D. per acre per day and maximum removal was 173 lb per acre per day. Over favorable seasons the Kearney lagoon removed 127 lb of a mean daily B.O.D. load of 157 lb per acre, an efficiency in excess of 80 per cent.

Lagoons provide almost astounding removals of coliform-type bacteria. Dakota lagoons have shown very high reductions. The Kearney lagoon reduced median coliform MPN by 95 per cent over the entire operating period. Daily removal was frequently as high as 99.9 per cent.

Alkalinity and hardness are normally reduced during seasons favorable for photosynthesis, but may become more concentrated during winter. Nitrogen and phosphorous compounds are markedly lowered by algal activities, nitrogen being most commonly utilized in the ammonia form. Settleable solids are virtually eliminated, as are total suspended solids of sewage origin. However, suspended solids frequently show great increases with development of phytoplankton. Chlorides usually increase in concentration during winter but are otherwise little affected. The surfactant portion of synthetic detergents is but slightly reduced but phosphorous components are largely utilized by algal growths. Surfactants lower surface tension and many lagoons never develop waves or even ripples from wind action. Lack of surface disturbance does not appear to appreciably restrict circulation, especially in larger lagoons.

Application

Lagoons are unquestionably well suited to sparsely populated areas where land is readily available at a reasonable price and where ice cover exists during extended periods of low solar radiation. They are solving sewage treatment problems of many towns in such regions at a fraction of the cost involved in treatment works of conventional design. They have also been advantageously used in areas with warmer climate and higher land valuation.

Where land cost is a significant factor, studies to determine maximum permissible loadings are very desirable. The Public Health Service plans to soon initiate studies at experimental facilities in Missouri and Ohio, in cooperation with the respective State health agencies, to more closely delineate features associated with the loading factor. Development of lagoons has proceeded largely along a practical path and few definitive design criteria for realistic loadings now exist.

Lagoons, by virtue of their low initial and maintenance costs, have accelerated the rate of pollution abatement progress in the Midwest. Many municipalities, now adequately handling their waste problems with lagoons, would still be discharging untreated wastes if they had been forced to wait until able to afford more conventional sewage treatment facilities. Satisfied city officials are enthusiastically recommending them to sister municipalities, and we know of one town that constructed its lagoon prior to completion of its sewerage system.

Lagoons are apparently fulfilling a long recognized need, and they appear to offer the best hope for early abatement of water pollution in many localities. In addition, they are making possible sanitary sewers in numerous areas where this basic public health facility was not previously feasible because of the high cost of conventional sewage treatment for villages and small towns.

RAW SEWAGE LAGOONS OPERATING IN MISSOURI BASIN STATES—JAN. 1, 1956

Location	Population Served	Number of Cells	Total Area (Acres)
COLORADO			
Alamosa	6,000	3	47
Altura (S.D.)	2,000	2	20
Fountain	2,000	2	3
Keenesburg	150	2	5
Kersey	245	—	—
Norwood	300	1	7
Nucla	500	2	5
Otis (S.D.)	250	1	4
Strasburg (S.D.)	400	1	5.5
KANSAS			
Frankfort	1,000	3	15.2
MINNESOTA			
Albany	1,075	2	50
Warren	1,600	2	51
MISSOURI			
Alam	350	1	3
Clay Co. (Sherwood Est.)	175	1	—
Jackson Co. (Fairlane)	1,520	1	3.1
Jackson Co. (Western Hills)	1,250	1	3.25
Montgomery City	1,200	1	12
Paris	1,100	2	15
Perry	500	1	5
MONTANA			
Big Sandy	700	1	9
Brady	240	1	2.74
Brockton	350	1	2
Charlo	250	1	2.8
Chester	700	1	9
Choteau	1,600	1	30
Circle	600	2	15
Denton	440	1	4.8
Dillon	4,000	1	40
East Helena	1,200	2	14
Fairfield	800	1	10
Geraldine	400	1	5
Jordan	650	1	4.4
Opheim	400	1	7.5
Plentywood	1,500	2	30
NEBRASKA			
Ceresco	325	2	1.55
Greenwood	365	2	3.45
Lodgepole	555	2	7.3
Plymouth	350	2	3.6
Waverly	300	1	3.35
NORTH DAKOTA			
Beach	1,350	2	20
Bisbee	320	1	13
Butte	250	1	1.75
Cavalier	1,350	2	16
Center	300	1	5
Dunn Center	200	1	4
Elgin	500	2	12
Fessenden	700	1	12
Flasher	300	1	5
Flaxton	350	2	10

Location	Population Served	Number of Cells	Total Area (Acres)
NORTH DAKOTA cont			
Fordville	310	1	3
Ft. Berthold Ind. Res. (1)	240	1	2
Ft. Berthold Ind. Res. (2)	240	1	1
Ft. Berthold Ind. Res. (3)	100	1	1
Golva	160	1	2.5
Hope	350	1	10
Jamestown	10,000	1	130
Larimore	1,230	1	12
Maddock	700	3	32
Max	400	1	5
Medina	500	1	5
Minnewaukan	350	1	5
Minto	500	1	10
Neche	550	1	11.5
New England	1,000	1	15
New Salem	800	1	10.5
Newton	350	1	10
Northwood	1,000	2	16
Park River	1,400	2	32.6
Plaza	300	1	4.13
Portland	400	2	18
Richardton (Ascension Abbey)	400	1	1.2
Rolette	400	1	10
Rolla	1,100	1	15
Scranton	320	1	4
Watford City	1,200	2	15
Wildrose	400	1	10
Wishek	1,250	1	7.8
SOUTH DAKOTA			
Beresford	1,600	2	16.5
Bison	300	1	1
Bonesteel	450	1	5.4
Clear Lake	1,100	1	12
Freeman	925	1	9
Gettysburg	1,500	2	20
Hayti	400	2	5
Isabel	475	1	2.7
Kadoka Winter	500	—	—
Summer	800	2	8.2
Lemmon	2,600	1	25
Murdo	730	1	9.3
New Effington	200	2	3.7
Philip	750	2	5.7
Pierre (4)	100 to 200	2	0.88
Pollock	350	2	4.6
Redfield	2,600	1	30.2
Sisseton	2,800	2	27
Wall Winter	500	—	—
Summer	1,000	2	11
WYOMING			
Casper (Air Base)	50	1	—
Newcastle	4,500	1	33
Osage	300	1	1.75
Pavillion	240	1	3
Sundance	900	1	9.1

(S.D.)—Sewer District
(1) —Western School
(2) —Eastern School
(3) —Southern School
(4) —Oahe Dam Administration Area

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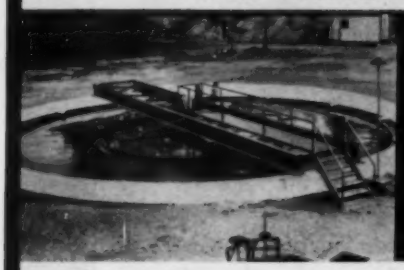

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. . the CAVITATOR, a newly developed Yeomans unit for low cost treatment of both domestic sewage and industrial wastes. Perfectly suited for small communities, subdivisions, motels, resorts, schools and industrial plants, the Cavitator has excellent purification efficiency, extremely high oxygen transfer efficiency, and extremely low air requirements per pound of B.O.D. removed.

. . the WATER-WHEEL, a rotary distributor used with trickling filter systems in the secondary treatment of sewage. An exceptionally rugged, yet simple piece of equipment, the Water-wheel provides uniform distribution over the entire filter bed at all flow rates . . even the lowest. Costly accessories, such as underground feed pipe, dosing chamber with siphon, center support, and mercury seal, are not required.

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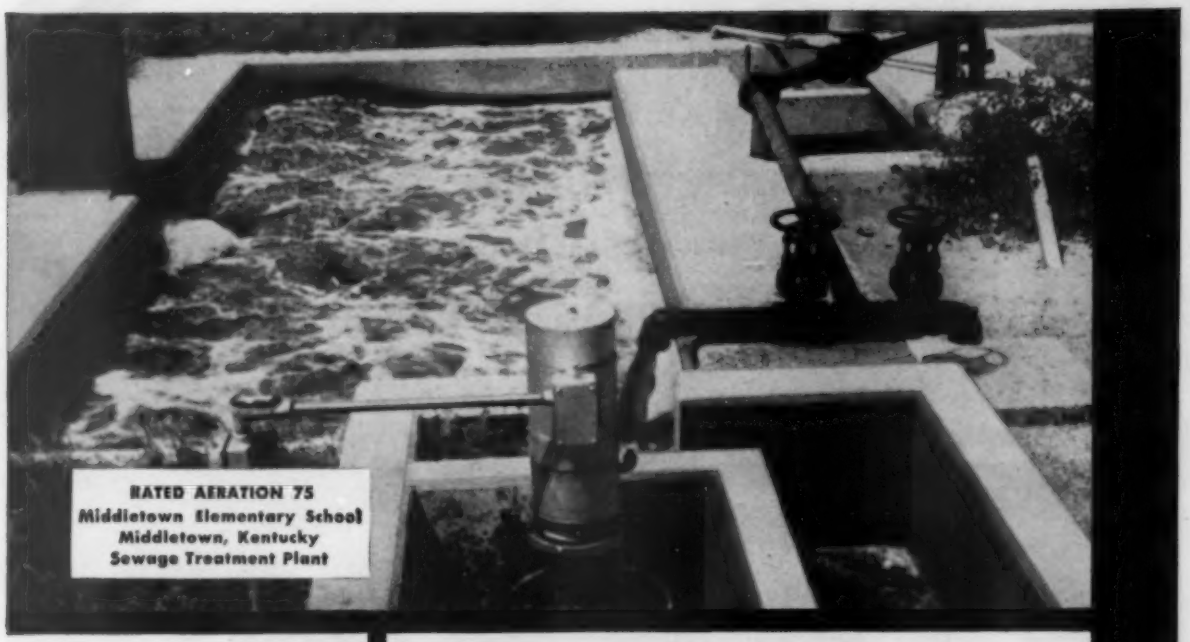

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Trickling Filters

by DON E. BLOODGOOD
Professor of Sanitary Engineering, Purdue Univ., Lafayette, Ind.

IN THE ARTICLE on trickling filters in the first series of these papers* there was only a brief summary given on the reportings of others. This current paper is devoted exclusively to the previously published material on the rates of application to, bacterial growth on, time of passage through, size of media in, rates of removal by, and ventilation of trickling filters.

It is always a good plan to have knowledge of the opinions of prior workers when undertaking to understand a particular process.

**Water & Sewage Works*, 101, 193, (Apr. 1954).

Treatment Obtained at Different Depths

Buswell[1] compiled in 1928 quite a detailed historical account of trickling filters up to the time of his writing. He wrote that, "Although much has been learned about the theory and operation of the sprinkling filter in the past 25 years, many of its interesting problems are still awaiting solution. One of these problems concerning which there is a difference of opinion, is the determination of the relation of the depth of the filter to the degree of purification."

Buswell reported extensive studies and concluded that no great benefit was obtained by having filters deeper than six feet. In the next quarter century after he made the foregoing statement, filters have been built with depths greater and less than the six feet that he recommended. This statement is not a contradiction and is only made to bring out the point that there is still a question in the minds of some as to what the correct depth should be. Buswell took samples at different depths in the filters. The analyses made on the

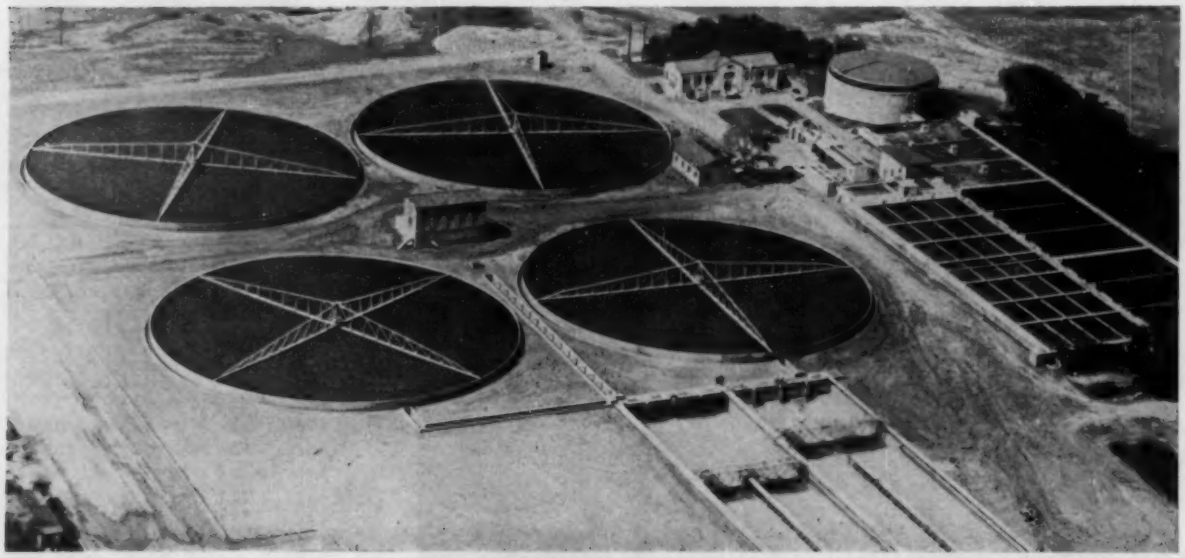


Photo courtesy Dorr-Oliver

TRICKLING FILTER distributors at El Paso, Texas, sewage plant are 220 feet in diameter, among largest ever built

MEDIA on 10-foot deep filter at Mansfield, Mass., plant of Hercules Powder Co. passed 4½-inch square opening and was retained on 3-inch round opening. Side walls are of wood stave construction

samples were to determine the progress of nitrification in the filters. There were some B.O.D. tests made, but not enough to make it possible to draw any definite conclusions.

Smith[2] made studies at Rutgers taking samples at different depths, but no record could be found as to what the depths actually were.

Rudolfs'[3] work, reported in 1923, showed the results in nitrification that were obtained at different depths. In his paper he had this to say: "And it would be reasonable even to assume that sewage which flows more slowly over active film surfaces with greater surface contact would undergo greater chemical change, than a larger volume flowing more rapidly. The amount of chemical change per unit volume is a function of the time and surface of the liquid exposed to active film."

Wilson and Hamlin[4] made studies with a 5-foot deep experimental filter. They show that there was considerable difference in the degree of purification obtained when the filter was dosed at different rates.

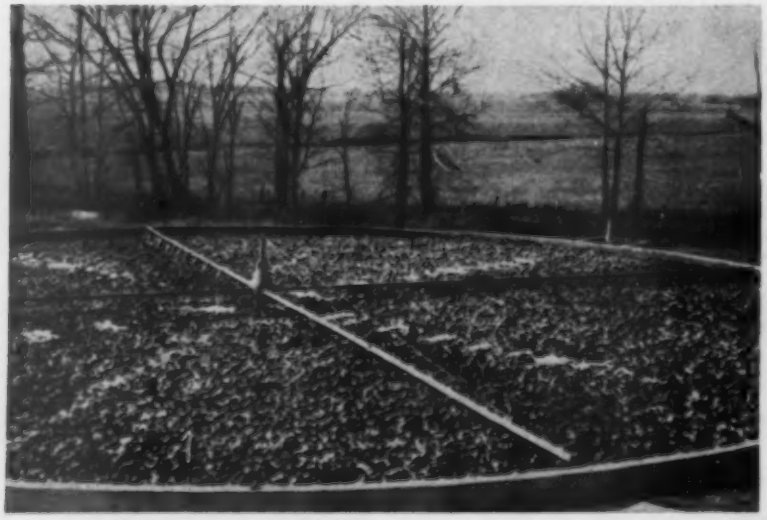
Butterfield and Wattie[5] used particular cultures of bacteria in studying removals with laboratory filters 22 inches deep made up of ¼- to ½-inch diameter gravel. The tubes were 2 inches in diameter. They used synthetic sewage and it is believed that it had a B.O.D. of 106 to 193 ppm. The results that they report are worthy of being repeated and so are given in Table I. These same data will be used later to demonstrate the removals obtained in shallow filters.

Not all workers have believed that recirculation on filters increased the contact time between stones and sewage because Horton et al.[6] has written: "Increasing the recirculation rates decreases the time of contact between the sewage and the gelatinous material in the filter bed, and consequently, decreases the amount of purification."

Allen et al.[7] operated two experimental filters. "One was a single filter operated at 60 gallons per cubic yard per day; the other was an alternating double filtration unit operated at a rate of 240 gallons per cubic yard per day." In this work samples were taken at different depths in the single-stage filter.

Phelps[8] has made statements regarding the purification rates in trickling filters. He has said: "The B.O.D. in dissolved form is the most difficult to remove and requires protracted intimate contact with zoogloea for extraction. The mass of the zoogloea in the bed and in sloughing, as well as the extent and duration of contact, are dependent on the hydraulic rate of passage of the liquid medium through the bed. Obviously, there must be some limit to the quantity of B.O.D. which can be assimilated by the biological life of the bed. The limiting B.O.D. load, then, must be a function of the rate of biological oxidation and storage capacity for accumulation of B.O.D. within the bed. Obviously, also, the size of the medium (surface area per cubic foot) is a factor in the storage capacity." He expresses the effectiveness of a trickling filter by the equation

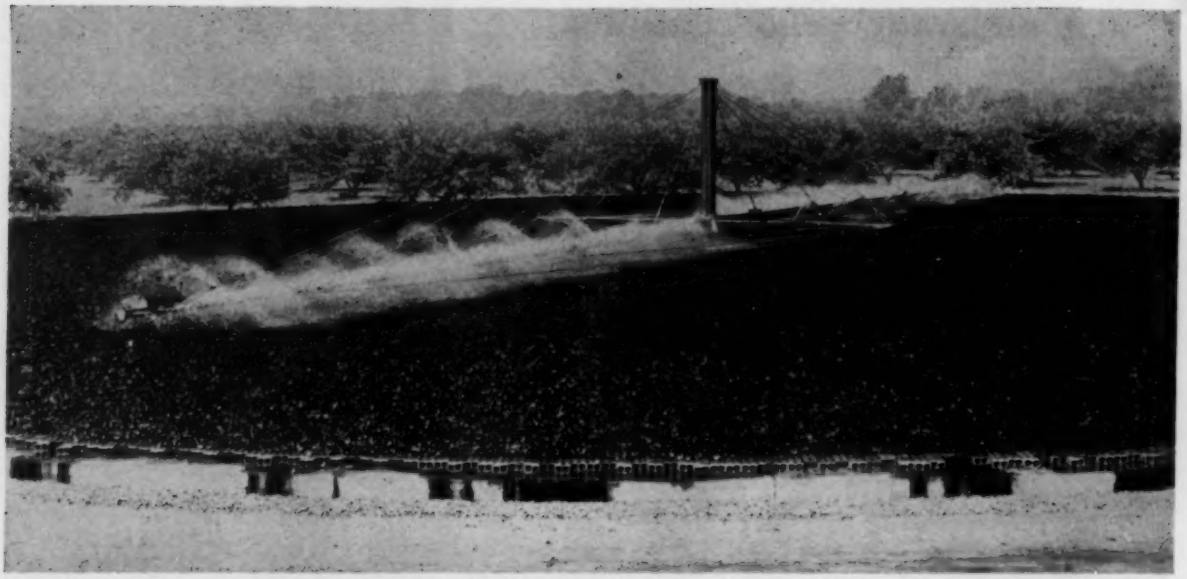
$$\frac{L_D}{L} = 10^{-KD}$$

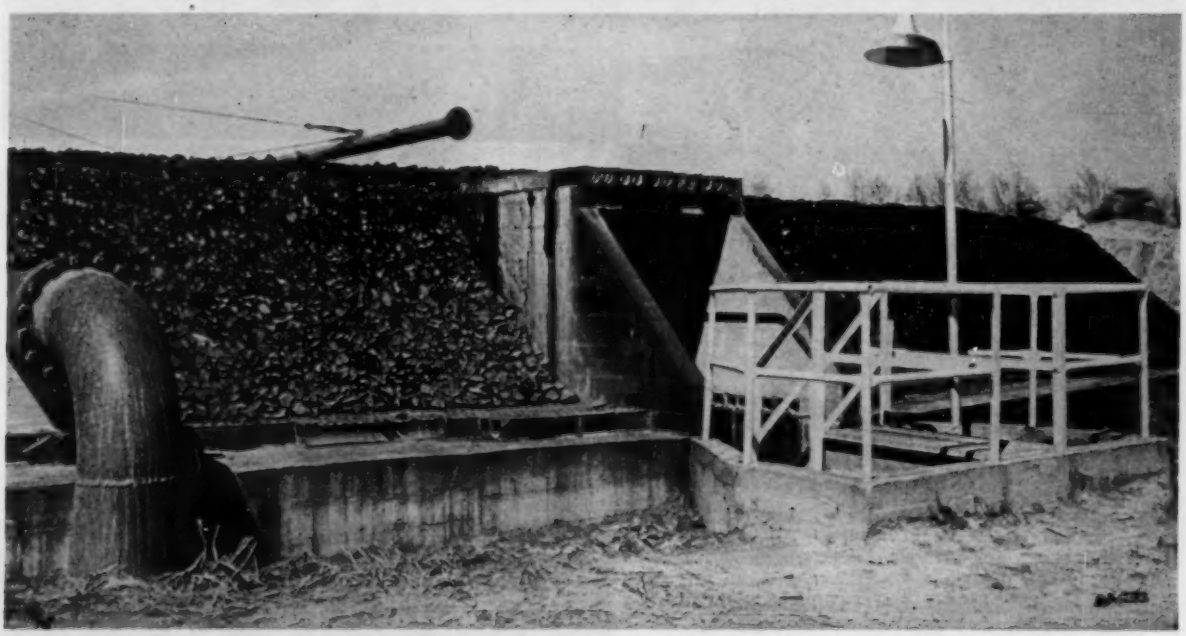


SMALL trickling filter at an Indiana sewage plant is typical of many across the country.

TABLE I
Removals from 22-Inch Laboratory Trickling Filter
(after Butterfield and Wattie[5])

Culture 86		Culture 87	
Flow, mgad	B. O. D. Removal, %	Flow, mgad	B. O. D. Removal, %
0.34	71.1	0.39	78.6
0.92	52.1	0.75	62.7
1.21	57.1	1.22	50.0
1.80	49.1	1.78	35.8
2.22	43.1	2.25	40.5
2.68	38.6	2.73	35.6
3.17	32.6	3.28	29.8
3.70	22.7	3.78	31.0
4.51	23.2	4.51	24.5
5.37	14.2	5.00	29.2
6.26	16.0	6.07	27.6
7.46	21.2	—	—





LARGE 5-foot deep filter at Bristol, Pa., plant of Rohm & Haas Co. has no side walls and large tunnel (lower photo) to obtain maximum aeration as liquid flows over media surfaces

where L_D equals the removable B.O.D. remaining at depth D, L equals the total removable B.O.D., D is depth, and L_D/L is the proportion of the total removable fraction remaining in the passing liquor at depth D. K is a constant: for low-rate filters, Phelps says that it is 0.175, and for high-rate filters it is 0.1505.

Grantham et al.[9] reports removals obtained at 2-foot intervals in an 8-foot filter being loaded between 2.2 and 7.0 mgd. Different media were used (1½- to 2½-in. slag, wood block, wood slat, Brookville limestone, and Chattahoochee River gravel). He states that these tests substantiate the Velz *Basic Law* that "The rate of extraction of organic matter per interval of depth of biological bed is proportional to the remaining concentration of organic matter measured in terms of its removability."

Keefer[10] has compiled considerable data on the degree of purification accomplished at different depths in a filter under different loadings. The loadings ranged from 2.68 mgad to 16.39 mgad. Samples were taken at 2.0-, 3.75-, 5.5-, and 7.25-foot depths. Tests were run on both settled and unsettled samples.

Film Growth

Gaultier[11] was interested in trickling filter operation and was concerned with obtaining information that would show the importance of the size of media, the volume of film formed, the amount of air required for ventilation and the time of contact between sewage and media.

Wishart[12] was interested in the amount of film that forms on the media. He used primary and second-

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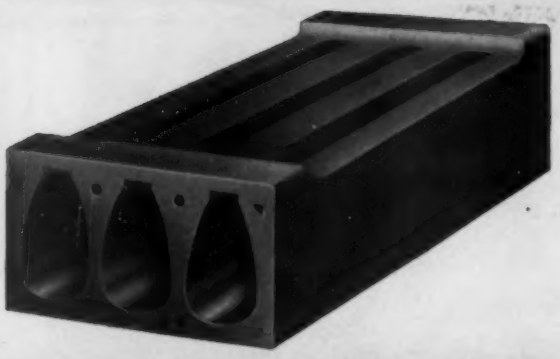
Close-up view of filter bed showing filter media directly on top of Unifilter Block Underdrain Floor at Sewage Treatment Plant in Worcester, Mass.

NATCO salt glazed UNIFILTER underdrain BLOCKS



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ary filters and he reports considerable film on the surface of the primary filter and very little film on the surface of the secondary filter. He observed further that when the filters were switched the growth on the surface of the filters also changed, with the growth on the primary filter always being the greater.

Heukelekian[13] made a study of film growths and he has recorded the weights of film under different conditions. He does not give information, however, on the amounts of film at different depths. In another article[14] in the same series he reports that there is about 2.5 grams of film per kilogram of stone.

Roberts[15] also was interested in the amount of film found on filter stones. The abstract of his article does not say whether he obtained information on the quantity of film at different depths.

Tomlinson[16] made parallel observations on a single filter and on two other filters operated as alternating double filters. The alternating double filters were operated at two or three times the application rate on the single filter. The fungal growth was reported to be greater in amount in the alternating double filter as it extended to about 3 feet below the surface, whereas on the single filter the fungal growth was confined to the top of the filter.

Ventilation

Levine[17, 18] in his experiments on filter ventilation showed definitely that elimination of bottom ventilation resulted in a rapid decrease in the purifying efficiency of a filter.

Dekema[19] experimented with deep enclosed artificially ventilated filter beds and compared the results with those obtained on an ordinary open filter. In his conclusions he stated: "The results indicate that the enclosed ventilated filter was able to substantially treat to the same degree of purity slightly more than 2.15 times as much of the same sewage per cubic yard of media as the open filter."

Reid[20] in his writing said: "The efficiency (of a trickling filter) may be increased by the addition of forced draft air or by the regulation, within certain limits, of the recirculation flow."

Hunter[21] reports on an 18-foot deep enclosed filter with air taken in at the top by a fan. He says that when the fan was shut down for three weeks the effluent deteriorated. Furthermore, he says that four years of comparative operation data showed that the enclosed filter treated twice as much sewage per cubic yard of stone as did an open filter.

Chase[22], in a general paper on trickling filter operation, says: "On the whole, the evidence seems to indicate that neither forced ventilation nor porous filter walls are essential."

Time of Contact with Media

Rudolfs[23] in experiments with stone, slag and gravel concluded that the time of contact with the media did not seem to be of much importance. The filters were 5.5 feet deep, were dosed at 1.96 mgad, and it took 460 seconds for the sewage to pass through the filters in each case. In an article published sometime later[24], he said that slag media seems to do a better job and that roughness of the media seemed to be an important factor. The slag was found to hold about twice as much slime as stone or gravel. He also found that 1½-inch media removed 64 per cent, while 2½-inch removed 47 per cent.

Blunk[25] made studies on the rate of flow through a filter and concluded: "Except for the amount (sewage) which is retained in the filter, the sewage seems to flow through the filter in 20 minutes. The amount of sewage retained depends upon the surface of the material and the size of the stones used."

Goldthorpe[26], in conducting some experiments with high-rate filtration in 8-foot filters with 2- to 4-inch clinker, found that the contact time was 20 to 25 minutes at 10 mgad and 7 to 9 minutes at 20 mgad.

Schaetzle[27], in a discussion of trickling filters, says: "The original experiments in this country were by Hazen in 1892. In 1909 Rudolph Herring combined the three variables of bacterial surface, air supply and time of liquid passage through the beds into a formula giving the degree of purification. His reasoning was that the media size affects the area of bacterial film and both size of media and depth of filter are directly related to the time of passage."

It must not be assumed that the 27 references are all that are worthy of discussion. These have been selected because of some particular point that they bring out.

Discussion

Professor W.E. Howland of the Purdue School of Civil Engineering has taken the data presented by Keefer[10] and has analized them. When these data are plotted on semi-log paper and compared with the curves presented by Phelps[9] it is apparent that the Keefer data do not lie on a straight line. It would seem likely that the Keefer data substantiated the statement made by Phelps[28]: "It is likely that there are two different processes taking place in the trickling filter; coagulation and precipitation in the upper foot of the filter and biologic absorption and oxidation in the deeper part of the filter." However, the greater removals at the top may be due to the improved aeration or ventilation at the surface. It seems quite unlikely that aeration plays so important a part as to give the great difference in activity shown in the Keefer data. It must not be forgotten, however, that a number of researchers in the past have pointed out that they have found that improved ventilation has

increased the effectiveness of the filters with which they were working.

There has been no careful evaluation made of the amount of air necessary to give maximum performance.

Several of the researchers have done work with media of different material and sizes. The indications seem to be that the larger media are not as effective as the smaller sizes. There are indications that the rough surfaced media do the most work per unit of volume. There seems to be no definite proof, however, whether the rougher stone retards the flow through the filter or whether the stone is more effective because it can hold more slime.

Howland has written a formula that fits the data presented by Keefer. The Howland formula is:

$$\% \text{ remaining} = 75 \times 10^{-2y^1} + 25 \times 10^{-0.1142y^1}$$

$$y^1 = \frac{\text{depth of filter, feet}}{(\text{flow, mg per acre})^{\frac{1}{3}}}$$

This equation takes into account the two rates of removal. It would seem, therefore, that the time of retention in the filter is a function of the rate of application.

Time of flow through a filter, then, should be a very important factor in considering the possibilities for increasing the loads to be applied to trickling filters.

There seems to be some indication that there is a great deal more slime growth on stones at the top of the filter than there is at the bottom.

Summary

It is apparent that there has been considerable written about trickling filters, but that not all of the published information is in agreement. Furthermore, it would seem that additional information should be compiled in an effort to establish definitely certain basic concepts about the operation and behavior of trickling filters.

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Air Diffuser Maintenance

by FRANK C. ROE

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THE SUCCESSFUL development of the original activated sludge process of sewage treatment in 1914 precipitated a remarkable series of process and equipment improvements. These have continued without interruption to date and there is no indication that such development will cease. Certainly, this is a credit to the basic effectiveness and economy of the process.

Progress of this character, of course, is a normal phenomenon for any successful process. In the case of activated sludge treatment, it has been based on these equally normal objectives:

1. Desire for increased efficiency (of oxygenation),
2. Desire to reduce maintenance generally and thus minimize cost of aeration.

Pointed towards the first objective of increasing efficiency, many devices and/or methods of aeration have been tried; *some of them more than once,* and several of them patented. A great deal has been written on this subject involving, for example, the relative values of air diffusion and surface oxygenation from the atmosphere, but that comparison is beyond the scope of this outline. A thorough consideration of all ideas leads to two basic conclusions: (1) That diffusion of air bubbles has proved to be the most efficient method of aeration, and (2) that porous ceramic diffusers similar to the type originally found to be most efficient continue as the standard and most satisfactory device or material to accomplish the job, all factors considered.

The greatest increases in oxygenation efficiency have come about by improvement in aeration tank design and diffuser distribution. Specifically, the two major improvements have been: (1) The use of "spiral flow" tanks instead of "ridge and furrow" and (2) the spreading of diffusers to give a wider air bubble column in such spiral flow tanks.

A third major improvement appears to have been established within recent years in the form of the Kraus distributed air process. Actually, this makes use of both improvements (1) and (2), but the unique idea of introducing air in two different locations for the separate functions of circulation and oxygenation, with proved overall air economy, is certainly new and outstanding.

The Maintenance Problem

The second objective of reducing diffuser maintenance is the prime subject of this outline. Basically, it involves keeping diffusers clean so that blower pressures and power cost will not increase unduly. An analysis of plants in service for ten or more years shows that many have required little diffuser servicing. The same survey indicates however, that maintenance of diffusers at a satisfactory level of efficiency frequently is a serious problem.

Figure 1 illustrates the magnitude of blower pressure increase when clogging develops and/or diffusers are not maintained in a clean condition. This was prepared by Superintendent J. J. Wirts of Cleveland's Easterly plant and provided cogent evidence to justify a diffuser servicing program. An analysis of each plant's experience would be too involved for this outline but the marked decrease in pressure loss from the maximum recorded at Cleveland (and elsewhere) indicates the eminent success of such a diffuser servicing program.

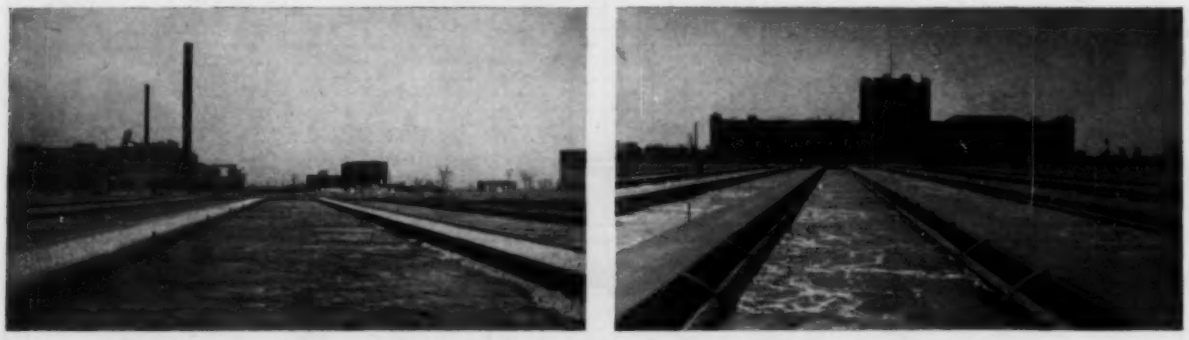
Diffuser clogging invariably is caused by one or more of the undesirable conditions that will be described in the following section. *Prevention of clogging usually is possible, as evidenced by the experience at many plants and should be practiced to the utmost within economic limits.* Prevention commences with the original *design* of the diffuser system. A favorable environment can then be maintained by means of good *installation* and *operation.* These three important prerequisites are described in the three sections that follow the outline of clogging sources.

Sources or Causes of Diffuser Clogging

Clogging is experienced on either or both the air and the liquid side of air diffusers. The various well established causes, with a few being somewhat theoretical, are given below. Both types of clogging are listed in the approximate order of incidence. The order of listing has no significance as to degree or seriousness of clogging, however.

Air Side Sources

1. Dust, pollen or smoke particles in air supply.
2. Rust and/or other oxidized or foreign particles picked up in air supply system following filteration. Generally this is air piping scale, but there



AERATION tanks, Chicago, Ill. Left, Calumet Plant; right, North Side Plant

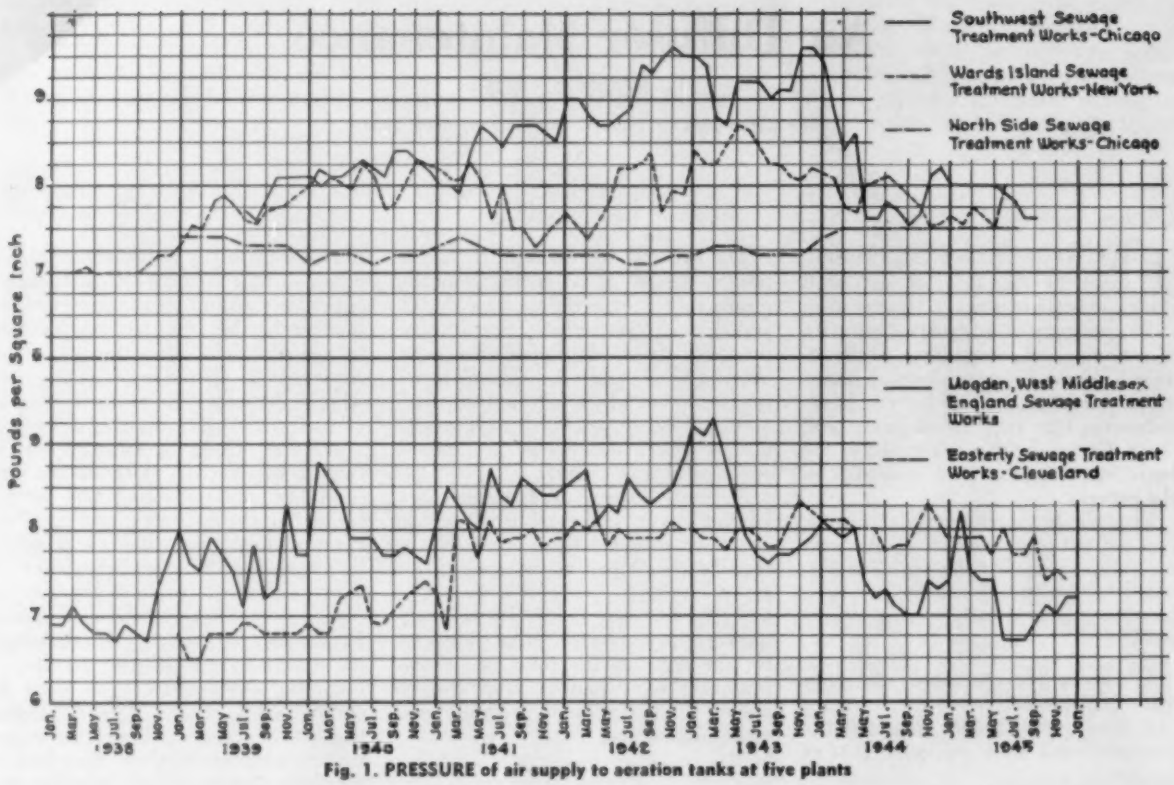


Fig. 1. PRESSURE of air supply to aeration tanks at five plants

are other contributory sources as suggested.

3. Oil in air supply from filters or internally lubricated (reciprocating) compressors.

4. Sewage solids resulting from leaks into the air system when air supply is interrupted.

5. Condensation of moisture from air supply, especially during periods of high humidity. While this does not cause diffuser clogging in the true sense, the effect of increasing air pressure loss when water enters diffuser pores is the same. It is not noticeable with clean, new diffusers but may be 10 per cent or possibly more when clogging from some other source is existent. Tests in The Carborundum Co. laboratories on 20 grade plates clogged principally as per source 1. below, showed an 8 per cent pressure loss increase (at 4 cfm. per sq. ft.) with air ranging from 20 to 90 per cent relative humidity.

Liquid Side Sources

1. Finely divided inorganic solids (silt) and sludge solids which enter the porous diffuser structure when air supply is interrupted.

2. Precipitated coating; principally iron salts from industrial wastes and carbonates where water supply is hard.

3. Organic growth or fungi.

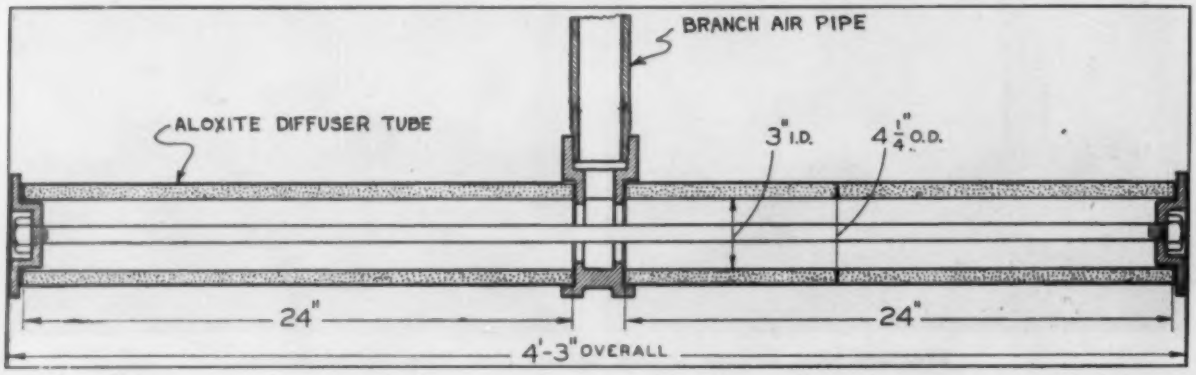
4. Grease.

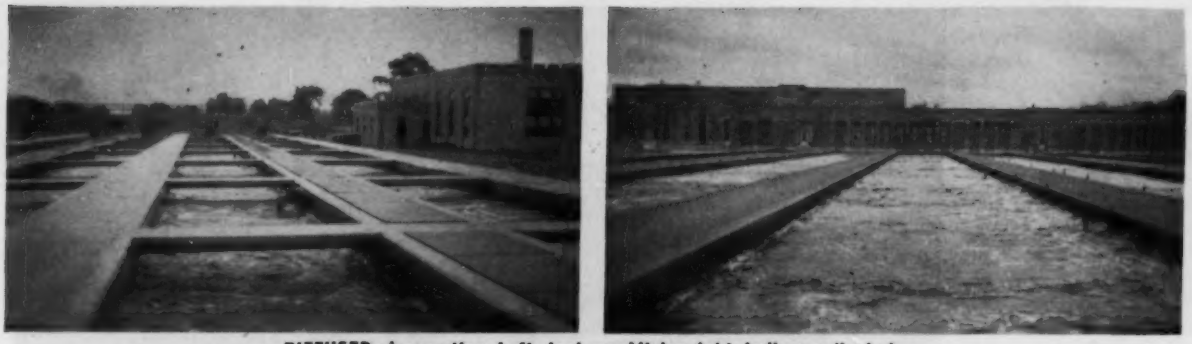
5. Miscellaneous debris during periods when diffusers are exposed in empty tanks.

It is apparent upon reviewing this double list that an astronomical number of different combinations of causes of clogging is possible. No single combination is decidedly the normal case in practice. It is no more likely that two installations of air diffusers will have identical operating conditions with the same combined possible sources of clogging than it is that any two analyses of sewage and industrial waste will be similar. Consequently it is evident that each plant must develop its own best schedule and method of diffuser maintenance and cleaning if cleaning becomes necessary.

Diffuser Design and Specification

Recognition of the maintenance





DIFFUSED air aeration. Left, Jackson, Mich.; right, Indianapolis, Ind.

problem and efforts to minimize it have resulted in two basic advances in diffuser design: (1) The use of stationary plate or tube holders that permit simple removal of diffusers following tank dewatering and (2) the use of completely removable diffuser units (usually tube assemblies of which Fig. 2 illustrates the first example) without tank dewatering. Selection of either design is based on overall economic factors.

There are now no less than seven (7) sewage treatment equipment manufacturers in the United States which offer complete, ready to install diffuser assemblies, the air diffuser units of which are easily replaceable. A multiplicity of such units can be utilized in the form of complete stationary aeration equipment which is accessible only through aeration tank de-watering. Or completely removable equipment is available, comprising one or more assembled diffuser units. These can be lifted out of aeration tanks for servicing while tanks remain in use.

Actually, it is increasingly apparent that the need for completely removable diffusers (without tank dewatering) has been over-emphasized. The recognized good practices stressed in this report minimize the need for diffuser servicing to the point that the extra cost for such completely removable diffuser units is not justified. There will be exceptions to such a general conclusion particularly in the case of small plants where it is undesirable, if not impossible, to dewater or by-pass aeration tanks.

A more important advance has been in the selection of higher permeability (grade) diffusers, with correspondingly larger pore size. It was presumed originally that small pore diffusers were essential to the release of minimum size air bubbles; hence, maximum efficiency or oxygenation therefrom. Periodic work by A. J. Beck of The Sanitary District of Chicago throughout the past twenty years has established that there is little increase in bubble size between grade 20 and grade 80 diffuser plates. This is due to the fact that in a body of sewage etc. having a relatively low horizontal velocity component, bubbles must attain a diameter of approximately 0.1 in. before buoyancy overcomes surface tension and they are released.* The negligible difference in bubble size, as established by photographs, is sustained by the fact that dissolved oxygen in tanks aerated by small pore diffusers is the same as in tanks aerated by coarser grades.

The above phenomenon is fortunate because the prime justification of large pore diffusers is the critical fact that they are not so effective in intercepting minute foreign particles from the air supply as small pore diffusers; hence, they are not as susceptible to clogging on the air side. Of some added economic importance is that initial pressure loss through the larger pore diffusers is lower and that they probably respond better to cleaning methods.

Figure 3 provides a close approximation of the relation between average pore size of diffusers and grade of standard ceramically bonded aluminum oxide diffusers manufactured by The Carborundum Co. Since the grade is based on permeability of 1 in. thick material (the standard for plates), it is apparent that thinner wall standard tubes will have a higher permeability for the same grade and pore size. Because of this fact it is recommended that all diffusers be specified on the basis of "grade" in order to obtain the desired pore size.

Grade 40 diffusers generally are recommended where air supply can be maintained in a clean condition. Grade 60 or grade 80 are suitable where air cannot be filtered satisfactorily but good initial air distribution may be more difficult with these low pressure loss units. Orifice control can be added to assure uniformity although equalization of pressure loss throughout a system normally is obtainable with branch air line valves.

To a considerable extent the fore-

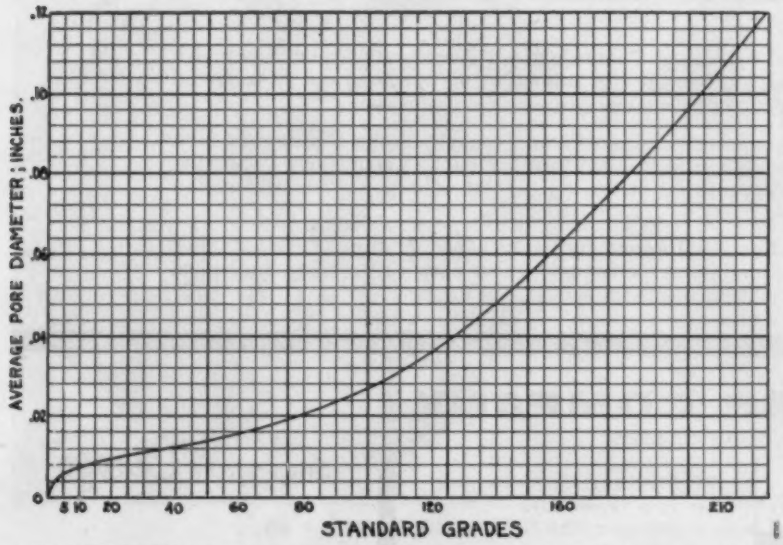


Fig. 3 RELATION between average pore size and grade of aloxite porous media

* A high liquid velocity across the surface of diffusers would tend to "wipe" air bubbles therefrom as they are formed. Under such conditions the small pore diffusers theoretically would provide more efficient oxygenation.

"from Chicago"

the aeration story

FINE BUBBLES +

WIDE BAND AERATION +

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maximum oxygenation efficiency for high treatment at low cost

Since their installation at the Lima, Ohio Sewage Treatment Plant shown above, Chicago Pump Company Swing Diffuser Aeration Equipment and Precision Tubes have operated for over a year with no problems whatsoever. Plant records show excellent results in high grade effluent for the aeration tanks with Chicago Pump Company equipment. From January through May, 1956 this plant handled an average of 8 M.G.D. using an average of 0.498 cubic feet of air per gallon of sewage.

Fine bubbles, provided by Chicago Pump Company Precision Diffusion Tubes, give far greater contact of air and sewage (for equivalent air volumes) due to increased bubble surface, and result in maximum oxygenation absorption.

Wide Band Aeration, through Chicago Pump Company Swing Diffuser Aeration Equipment, produces a wide mass of finely divided bubbles completely circulating through the entire tank contents, increasing contact efficiency while eliminating center "coring."

Swing Diffuser Aeration Equipment for wide band aeration provide flexible economical operation, continuous performance and easy accessibility. Individual units are easily raised for service without de-watering the tank.

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going DESIGN requirements, in addition to those listed under INSTALLATION and OPERATION to follow, are premised on the discussion of each subject in the Air Diffusion Manual of Practice No. 5 published by the Federation of Sewage and Industrial Wastes Associations. It is beyond the scope of this outline to give further specifications. They are covered in greater detail in the Manual.

Diffuser Installation

To prevent as much clogging as possible from the sources as outlined, minimize maintenance expense and generally insure maximum efficiency of air diffusers, there are several somewhat obvious requirements of initial installation as follows:

1. The type of air filter equipment selected and its capacity must be such as to provide a supply that will not contain more than 1.0 mg. of foreign particles per 1000 cu. ft. under the worst anticipated atmospheric conditions. A concentration of 0.5 mg. per 1000 cu. ft. is the standard recommended for average conditions. Double air filtration normally is necessary for this quality.

It has been established very recently that secondary air filtration by electrostatic or automatic electronic filters actually will produce air having a concentration of foreign particles consistently as low as 0.01 to 0.03 mg. per 1,000 cu. ft. Performance of this high caliber has resulted in practically no increase of pressure loss through porous ceramic diffuser plates at Chicago's West-Southwest Sewage Treatment Plant between 1949 and 1956.

The practicability of utilizing electronic secondary filters may be shown by comparing its total cost with the cost of servicing diffusers, which may comprise special diffuser removing equipment, a cleaning program and progressive diffuser replacement. To establish a full and proper comparison of cost, with and without electronic filters, the factors of oxygenation efficiency and power cost for air blowers should be correlated with all other aeration cost factors under both methods of operation. This is more complicated but is justified for the larger plants.

2. Air mains and branch air piping should be of such a material and so protected that there will be no scaling or other deterioration that will result in serious clogging of diffusers from the air side. For the same reason, all air lines must be thoroughly clean before operation commences.

3. The blower equipment selected must be of the type that will not contaminate the air supply with its lubricating oil or other foreign material.

4. All diffusers controlled by any given valve should have the same permeability rating within one (1) percent.† All diffusers on the same system should be installed level and to the same elevation within 0.05 ft. Those tributary to each valve should be at the same elevation within 0.02 ft.

5. The entire aerator system should be initially tested for leaks with clean water above diffusers in order to prevent sludge solids from entering the air system during possible subsequent shutdowns. The system should then be protected until actual operation commences when the air must be discharged before liquor is introduced.

6. The general plant construction, source of blower power, aeration accessories etc. must be such that air supply shutdowns will be non-existent except as a result of unavoidable accident, catastrophic storm or similar occurrence.

† Where orifice control is included with individual diffuser tube units this close control is unnecessary but it normally is possible on a given shipment of standard tested tubes.

Diffuser Operation

An aeration system must be operated in accordance with certain well established practices to keep maintenance cost and diffuser clogging at a minimum, thus requiring low blower pressure and producing generally high efficiency. The various factors involved as listed below are of perhaps even greater importance than those comprising the requirements for proper INSTALLATION.

1. A continuous air supply is the basic operating requirement for prevention of clogging of diffusers from the liquor side. In addition to installa-

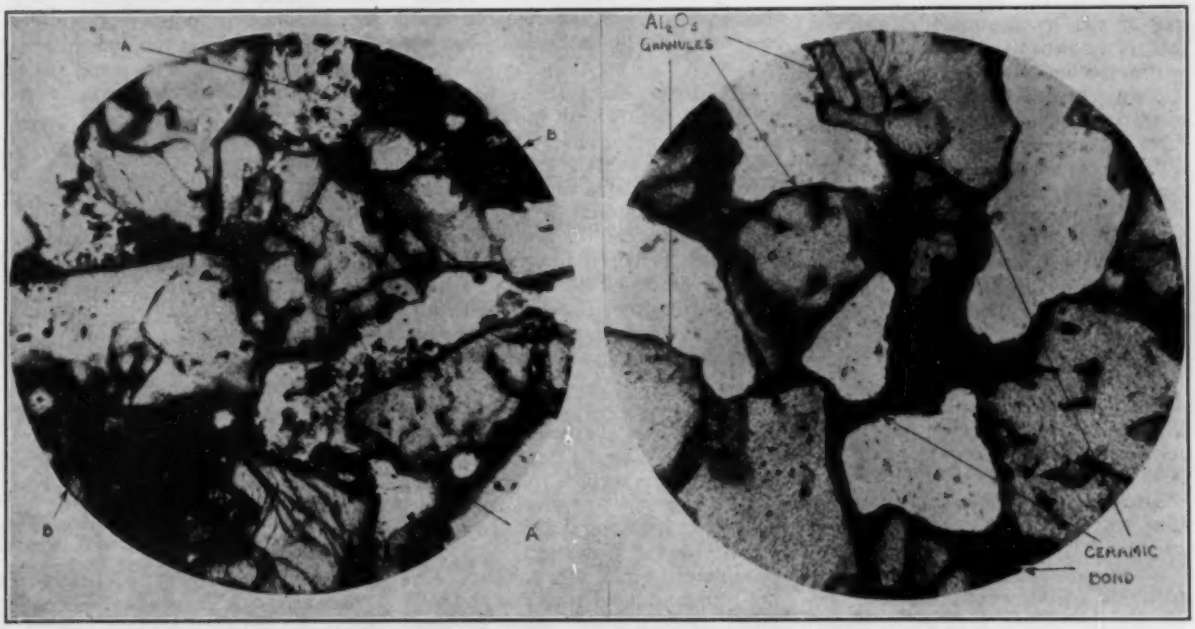

Fig. 4. PHOTO MICROGRAPHS (x50 magnifications) of Grade 40 Diffusers

Left, clogged plate structure; right, clean, new, plate structure

tion requirement No. 6 described above, it is apparent that thorough blower and motor or engine maintenance, e.g., lubrication, is absolutely essential to avoid shutdowns.

2. Air filters and electrostatic separation equipment must be constantly and properly maintained to prevent air side clogging.

3. Regular and thorough inspection of the diffuser system is essential to prompt location of leaks or nonuniformity, thus avoiding more serious difficulty.

4. Complete and continuous records of all aeration factors, e.g., blower pressure, likewise is essential to prompt discovery of any condition that ultimately may contribute to a decrease of diffuser permeability.

5. Control or prevention of clogging due to organic growths within diffuser media near the liquid interface may be effected by periodic applications of chlorine gas with air supply.

Methods of Diffuser Servicing or Cleaning

While the theme of this and previous outlines of diffuser maintenance has been prevention of clogging, the eventual necessity of permeability restoration through some degree of cleaning must be recognized as a strong possibility. If unavoidable conditions make the problem serious, a thorough analysis of the various known methods is justified. A regular schedule of servicing is then desirable, based on use of the most successful method that is economically justified and within the budget.

Two general procedures of cleaning have developed in keeping with diffuser design development: (1) for diffuser plates more or less permanently cemented in plate holders and (2) for diffuser plates or tubes that are easily removed from stationary or suspended type assemblies. These procedures can be broken down into methods used for liquid side clogging and those used for air side clogging. Rather than attempt a further classification based on methods used for different kinds of diffuser clogging, the established effectiveness of removing various kinds of clogging will be listed with each method.

Because of the practical certainty that any serious clogging is from a combination of sources, it is quite possible that a combination of cleaning methods will be required. For example, the left-hand Fig. 4 photomicrograph of a thin section cut from a 40 grade diffuser plate as taken from service, gives evidence of three sources of clogging. The areas marked "*A*" appear to be silt particles embedded in a precipitated coating that contains some iron. The darker areas marked "B" are chiefly the natural ceramic bond of the plate but the extended rough edges plus other minute dark spots indicate dust or some oxide particles from the air supply. The contrast with the right hand photomicrograph of a clean new plate of the same grade is quite striking.

A. Cleaning Plates in Place—Liquid Side

1. Acid Treatment has been used the most widely with different acids of variable strength and a variety of techniques or modifications. A concentrated solution containing 80 per cent sulphuric, 2 per cent sodium dichromate and 18 per cent water appears to be the most effective on serious clogging. Lower strength solutions, and also hydrochoric and nitric acids, should be tried because of cost factor.

The general technique is as follows: Clean plates by water hosing with air on; apply acid to center of each plate using approximately 150 ml. per plate; spread over surface with squeegee; allow to stand for a day or two; blow out with air. More or less acid may be applied depending on plate condition or the operation may be repeated before drying.

Variations of this technique and solution will be found effective for each situation and type of clogging. The method has been used for removal of organic solids, various precipitated coatings and growths from the top of plates.

2. Caustic Treatment has been used infrequently with indifferent results but conditions may warrant trial. One method used is to clean plates as described above and leave plates with a small amount of water on the surface: Dissolve 0.1 lb lye crystals over each plate; shut off air; allow solution to penetrate 10 to 15 minutes; add water; blow out with air.

This method is reported as most effective for removal of organic compounds, grease etc. from plate surface.

3. Ammonia Treatment has not been used frequently but is reported faborably. The method follows: Clean surface of plates by water hosing; include wire brushing if necessary; shut off air leaving plates wet; apply approximately 1 pint of a solution of 50 per cent household ammonia and 50% water to each plate; allow to stand overnight; blow out with air.

Method is applicable primarily to plates clogged with organic growths.

4. Detergent—Water Jet Treatment is the most recent method used and involves a combined operation. The detergent solution may be ½ pint of commercial liquid such as "Glim" mixed with 5 gal. of water and 1 qt. of ammonia. Another commercial liquid known as "Nacconol" is equally effective. The jetting which follows is considered to be an expulsion action within the saturated plate similar to water hammer.

Plates are washed first in usual manner and thoroughly blown out. About ½ pint alcohol is then poured on each plate as a wetting agent. The detergent solution is then applied until plate is saturated and allowed to soak overnight. The water jet cleaning which follows should be as violent and concentrated as possible. It can be accomplished with a 1 in. fire hose line at full pressure with nozzle reduced to ⅛ in. The jet is applied for about 30 seconds to each plate with the air off and then another 30 seconds with the air on, in order to locate spots that were missed by initial jetting.

While extensive experience is lacking on this method it undoubtedly removes all types of organic clogging on the liquid side. Inorganic solids also are loosened so that a high percentage is forced out upon jetting.

This method also should be applicable to the cleaning of suspended diffuser tube assemblies in place although there is no report to date of such use. A special "ring" device has been developed by Chicago Pump Co. for uniform circumferential application of water jets. It simply is inserted over the end of each tube and moved manually from end to end.

5. Chlorine Purging has been used in relatively few places but with some good results. It is undoubtedly the most simple method known except drying.

With no preparatory step chlorine is taken from cylinders and introduced into the air main at a convenient location; preferably near aeration tanks. The rate of application will vary to meet conditions but a starting point and estimate of requirement is 2 lb. per 100,000 cu. ft. of air delivered. The operation is continued until blower operating pressure is reduced and/or until an adequate supply of air can be delivered to diffusers. This may take from two or three days to as many weeks.

Chlorine treatment is effective in removal of organic solids and growths from the diffuser surface. There is an indication of some help in reducing air side clogging from unknown

Fig. 5. SOAKING and draining tank for acid treatment

Fig. 6. DIFFUSER plate flushing equipment

(Both at Cleveland Easterly Plant)

sources simply as a result of the continuous purging action.

6. SAND BLASTING is known to be effective and reasonably fast on silica type porous diffuser plates but slower, and therefore costlier, on aluminum oxide type plates. Blasting should be done during air discharge to avoid further clogging by removed particles and sand. It is estimated that 1 minute is required per plate to remove ⅛ in. from silica type plates or 1/32 Accumulated sand and disintegrated in. from aluminum oxide type plates. plate material must be thoroughly cleaned out of tank after operation.

It is self-evident that this method will remove all types of top clogging. The extent of the operation depends on the depth of solids penetration.

7. OXYACETYLENE FLAME SPALLING is effective in cleaning the surface of aluminum oxide type plates and is more economical than sand blasting but still quite costly.

The cleaning procedure involves preliminary plate washing and then setting a portable track alongside of plate holder as shown. Air is left on and the flame applied with nozzle moving over plates at linear velocity of 3 ft. per min. This removes approximately 1/32 in. from the surface and if clogging is deeper, the operation is repeated. Disintegrated plate material must be thoroughly cleaned out of tank after spalling.

This method may be applicable to any serious liquor side clogging. Equipment is available from Linde Air Products Co.

8. BLOW TORCH SPALLING is effective in cleaning silica type plates but is tedious and costly with increasing labor rates.

The procedure is to wash plates by hosing and scrubbing; dry with air discharge; apply blow torch flame at semi tangent with air on and remove material to required depth. Clean tank thoroughly after spalling.

As in all other methods involving removal of a thin layer of the diffuser material, blow torch spalling is effective on all kinds of liquid side clogging.

9. DRYING is the simplest method of all, involving no expense other than for the air supplied. After draining tank, air is blown through diffusers for two or more hours, finishing with an extra high flushing rate. This is effective only in removing light organic (sludge) solids from the surface of otherwise clean diffuser plates.

10. STEAM PURGING has been used rarely but is reported as effective. Low pressure steam is applied to the air line and simultaneously the surface of plates is brushed vigorously with a stiff brush. Organic clogging and grease are removed with this treatment.

Care should be taken with this method to bring diffusers up to steam temperature rather slowly and to avoid a cooling shock after completion. This precaution is to prevent thermal shock cracking of the ceramic bond of diffusers.

B. Cleaning Plates in Place—Air Side

1. SAND BLASTING has been satisfactory on silica type plates but has not been reported for aluminum oxide type plates. It involves removal of one end plate from each plate holder opposite air inlet and passing a sand blast nozzle under the plates by means of a special "boat" carriage.

The procedure is to dry plates thoroughly; remove end plate; insert boat with nozzle pointed upward 30° from horizontal; pass back and forth 3 times and swing nozzle from side to side enroute; remove and blow out plate holder at high rate with air from blower; clean sand and disintegrated plate particles from tank.

This method is effective in reduction of all types of air side clogging grated plate particles from tank.

2. GASOLINE PURGING has only been reported at one plant where it is effective in removing a sudden incidence of oily smoke that cannot be intercepted by the air filters. Aviation gasoline is introduced into the air line at a rate of about 2 gal. per mil. cu. ft. Precautions must be taken to avoid possibility of explosion.

This method should be applicable to removal of grease or oil from other sources.

C. Cleaning Removed Plates and Tubes —Clogging on Either or Both Sides

The above heading applies because all of the methods listed below are at least partially effective in removing both liquid and air side clogging and

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PROCESS . . . AND EQUIPMENT . . . FOR SEWAGE AND INDUSTRIAL WASTE

ACTIVATED SLUDGE TREATMENT

BIO-ACTIVATION PROCESS—a patented process combining and utilizing the best qualities of trickling filters and activated sludge in two stages and in such a manner that each stage operates under optimum conditions and at maximum efficiency. Primary treatment is followed by high capacity filters and short period intermediate sedimentation. Here, initial high removals of BOD are obtained before sewage is passed to aeration tanks where activated sludge is developed. Because of the intermediate filter treatment which considerably reduces the strength of the primary effluent, the liquor can be readily handled by the activated sludge process without the usual upsets caused by exceptional conditions and shock loads.

Send for Bulletin 259-B

A Typical Bio-Activation Plant

MECHANICAL AERATION—Consists of a circulating pump with down-draft tube and hydraucone assembly. As liquor passes through the pump, fine bubbles of air are drawn in and intimately mixed with the sewage. This mixture is ejected at high velocity across the tank floor. Consequently, entrained air is distributed uniformly across the tank, and fine air bubbles, rising slowly to the surface, supply sufficient oxygen to maintain the activated sludge process. For large installations, "AMERICAN" Aerators are installed in single, large tanks without dividing walls because the pattern of recirculation sets up hydraulic baffles between the units, thereby eliminating any possibility of short circuits.

Send for Bulletin 265-A

FIXED TUBE DIFFUSERS—Economically increases efficiency of oxygenation, with minimum maintenance. Use of flexible sleeve-type couplings throughout allows easy installation or removal of any section. Ever-increasing cross-sectional area at air inlet reduces friction loss. Porous tubes with gasketed cast iron end covers and tie-rod make tight assembly.

Jet Aerators also available. Write for information.

ROTARY DISTRIBUTORS—Reaction and Positive Drive Types. The Reaction type is manufactured with 2, 3, 4, or 6 arms. In general, the 3 arm distributor has the advantage of minimum wind effect, low starting inertia, and perfect balance. The Positive Drive type is rotated continuously independent of the sewage flow, by a motorized gear reduction unit. It is used under conditions of low available head and wide variations in flow. "AMERICAN" Distributors are equipped with a patented dual oil seal which eliminates troublesome and costly mercury, protects bearing surfaces, and will withstand at least 10' of water pressure.

Send for Technical Supplement "RD"

Send for Technical Supplement TV on Telescoping Sludge Valve

GRIT REMOVAL

AMERICAN CAMP REGULATOR—an adjustable control to maintain velocity of sewage flow thru grit channels at optimum rate, regardless of rate of flow thru plant.

Send for Technical Supplement "CR"

GRIT CONVEYOR—single strand, drag type. Carries grit to hopper for washing and removal.

GRIT HYDROWASH—grit washed free of organic matter by turbulent downflow recirculation of liquor in grit hopper.

GRIT ELEVATOR—tube type, totally enclosed for lifting well-drained grit to desired height. Manual or automatic operation.

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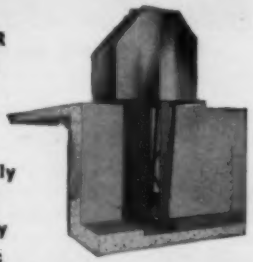
UNIT BAR SCREEN



Mechanically Cleaned Completely Automatic with Exclusive Pivoted Rake Design

SCREENING

MECHANICALLY CLEANED BAR SCREEN AND GRINDER—designed for wide range of channel widths, settings, and arrangements. Grinder attached to sorting tray . . . shredded screenings returned to sewage flow.

Send for Technical Supplement "MS"

PRE-TREATMENT

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors.

Send for Bulletin No. 260-A

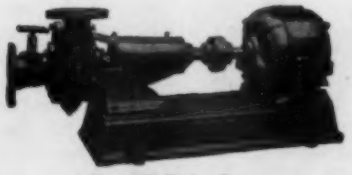


Fig. 5500 Sludge Pump

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

CIRCULAR CLARIFIERS—for round settling tanks.

SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 5400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5' to 85'.

Send for Bulletins No. 237-A, 250-A, 253-A, 261-A

because the simultaneous effect on both sides can hardly be avoided. The particular benefits of each method will be listed as heretofore.

1. ACID AND FLUSHING TREATMENT is perhaps the most widely used and generally successful method of all. While acid pickling *alone* is partially effective and also is used extensively, the water and air flushing which follows adds much to the result. The second step has been well worth the extra equipment investment in the larger plants where used.

The initial step is to wash diffusers by hosing down in aeration tank; then blow out and dry with air discharge before removal from plate holders or tube assemblies. Submergence in concentrated sulphuric acid (2 per cent sodium dichromate may be added) is the next step, using a large stoneware crock. Diffusers then are placed in a large rubber lined steel soaking tank, similar to Fig. 5 and allowed to soak for as much as 48 hours. This tank is equipped with a drain for removal of spent acid and rinsing water which follows.

Flushing or scrubbing the treated diffusers with water and air is accomplished by clamping in a device similar to that developed at Cleveland's Easterly plant, Fig. 6 (Water and air inlets are connected to the box below plates and are controlled by quick opening valves. Drains are connected to the trough around the outside and a cover provided to prevent initial acid and water spraying.) The flushing time is determined by the operator based on uniformity of air bubble discharge.

This method is most successful in removal of organic solids and precipitates from the liquor side of diffusers. In addition, the flushing action undoubtedly removes some of the loosened undissolved inorganic solids from both sides. The reported diffuser permeability recovery at Cleveland and Chicago (SW) by this method, is from 80 to 90 per cent.

2. REBURNING is unquestionably the most thorough method of cleaning known inasmuch as 100 per cent revivification is accomplished. If suitable kilns or furnaces are available, work can be done locally to save transportation. A more complete and satisfactory job probably can be done by the diffuser manufacturer with the type of kiln used for original vitrification.

Diffusers should be washed and dried before shipment for reburning. For ceramically bonded aluminum oxide diffusers, the process is to bring up to the maximum temperature slowly (about 50°C. per hour) and then cool at the same rate. The maximum temperature required for complete permeability restoration will vary with the kind of clogging elements present. Most materials burn out at low temperatures but silt normally is present containing small amounts of Si, Ca, etc. To fuse such elements into the structure and leave open pores, duplication of the maximum original vitrification temperature of approximately 1350° C., is desirable.

It is apparent that this is the most expensive method of cleaning, but it has these advantages: (1) recovery of diffusers equal to new diffusers, regardless of type of clogging; (2) accurately retested (for permeability) diffusers that will insure good initial uniformity of air diffusion upon reinstallation.

3. CAUSTIC TREATMENT is used infrequently because of limited attack on clogging materials. In some cases, it supplements other methods to advantage.

The treatment consists of placing washed diffusers in a suitable iron vessel and boiling for several hours in a 10 to 15 per cent solution of sodium hydroxide. The time may be from 3 to 8 hours depending on conditions. Boiling in water should follow short treatment to dissolve soap.

Caustic treatment is effective in reducing the clogging from grease and other organic solids. It frequently must be followed by acid treatment to show marked results due to presence of other clogging elements.

Repeated hot caustic treatment over a period of several years should be done with caution because the silica content of the bond is slightly soluble therein. The structure accordingly would be weakened.

4. DETERGENT—WATER JET TREATMENT has the principal steps as outlined for cleaning plates in place and can be followed for cleaning of removed plates or tubes.

Economics of Diffuser Maintenance

As stated in the introductory analysis and review of the maintenance problem, the entire basis of its consideration must be that of cost. The elements of plant operation cost are so inter-related, especially within the diffuser system or "heart", that the economics of maintenance are extremely complicated.

It is apparent that diffuser economics is a special and extensive subject in itself. This concluding section, therefore, will merely outline the factors closely related to diffuser cleaning.

With the exception of large activated sludge plants, it is doubtful that many plants keep a separate accurate accounting on: increase of power cost, diffuser maintenance, and replacement sinking fund, for the diffuser system. Such records are critical, however, in establishing a clear picture of this subject. They will enable management to know how far it is possible to go in each direction in order to preserve an economic balance and to establish a realistic budget.

Cost of cleaning by the various methods reported vary extremely because of the variable degree of treatment required in each case, as well as the variation in cleaning method, plant size, labor required and other local factors. It is impossible, therefore, to put a price tag on each method as listed in the foregoing section. Under 1950 conditions, the cost of cleaning would appear to vary from a minimum of perhaps $0.10 per unit for the most simple methods (except drying), up to about $1.75 per unit for reburning.

A somewhat forgotten, yet quite important, factor in this problem of maintenance, is that of diffuser permeability. In the first place, diffusers do not clog uniformly from inlet to outlet of tanks. The permeability, therefore, will decrease and the pressure loss will increase by variable amounts, resulting in non-uniform aeration and decrease in over-all efficiency.

When it comes to cleaning, it is obvious that all diffuser units will not respond uniformly to treatment so that considerable variation from original permeability ratings will result. Without retesting and subsequent reinstallation in accordance with specification No. 3 under INSTALLATION, a tank equipped with cleaned diffuser units would resume operation with some non-uniformity. There is an automatic tendency towards correction of initial non-uniformity, but it is believed that equalization takes place at a slightly higher pressure than may be necessary.

Most of the large activated sludge plants are equipped with diffuser permeability test apparatus. Where smaller plants find it essential to adopt regular cleaning, the installation of simple testing equipment will be found profitable.

Summarizing this phase of the subject, one can only return to the original theme, expressed by one word: *prevention*. Observation and practice of the factors of prevention as outlined herein will pay large dividends.

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DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.

W & T Series A-711 V-notch Chlorinator

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. V-notch chlorinators and Visible Vacuum Chlorinators with capacities from ounces to 8000 pounds per day—Solution Feed and Direct Feed Chlorinators for small plants—and Reagent and Chemical Feeders to meet many varied chemical treating applications. All W&T Apparatus is backed by over thirty years' experience.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent on request.

Sewage Chlorination

by V. W. LANGWORTHY
Development Engineer, Omega Machine Co.,
Div. of B-I-F. Industries, Inc., Providence, R.I.

THE application of chlorine, or its compounds, to water or wastes must be controlled within definite limits to insure economical and satisfactory attainment of established objectives. Chlorine is unique among water treatment chemicals, not only in its applications, but also in methods and equipment available for process regulations. Operators must be aware of the overall purposes of chlorination in order to control the processes which will achieve them.

Chlorination Objectives

Disinfection continues to be the foremost objective in chlorination of water and domestic wastes. Secondary purposes utilizing chlorine have developed, and pre-, post-, or plain chlorination may be practiced. The process has been extended from relatively simple plant effluent disinfection to include ramifications of intriguing complexity.

Disinfection

When chlorine is applied for disinfection, it would appear that measurements of bacterial destruction should be used to indicate the success of the treatment. Unfortunately, bacteriological methods are time-consuming to the extent that results become available too late to be of practical value in dosage control.

We have been forced, therefore, to accept an intermediate scheme of chemical testing which experience has shown to be adequate. Chlorine residual values have been accepted as the basis of control in the chlorination process. Bacteriological sampling has become a matter of spot checking to determine whether or not disinfection is actually being accomplished.

For purposes of disinfection, water or sewage may be chlorinated at the effluent end of the treatment process. Sufficient dosage must be maintained to establish a chlorine residual after a definite contact time. The magnitude of the chlorine residual required is determined by bacteriological sampling as noted earlier. The degree of bacterial kill required

W & T Photo

Fig. 1—AMPEROMETRIC Titrator to measure chlorine. Relative concentrations of free available and combined available chlorine can be determined.

W & T Photo

Fig. 2—CHLORINE residual recorders.

is extremely high in the case of public water supplies. The extent of disinfection required for sewage plant effluent varies, depending on local conditions.

It should be noted that of the chlorine applied, none can be depended on for disinfection until the chlorine demand has been satisfied. It is true that certain of the products formed in satisfying the chlorine demand will exert bactericidal action, but chemical analyses do not provide close enough correlation to permit dosage control on this basis. Sufficient chlorine must be added to establish a residual known previously to have been bactericidal.

Sewage Chlorination

Among the secondary purposes in sewage chlorination are: odor control, B.O.D. reduction, aid to settling, foam control in Imhoff units, preventing filter ponding, control of sludge bulking, assist sludge thickening, and reduce loadings caused by digester supernatant liquor return.

It is not possible for one application of chlorine to assist in solving all problems incident to sewage treatment. Upsewer chlorination can contribute to odor control and reduce the B.O.D. load imposed on the treatment works. Prechlorination at the plant entrance controls odors and might make substantial improvements in solids removal by the settling units.

Chlorination of primary settling tank effluent improves trickling filter operation, while chlorine added to return activated sludge serves to control sludge bulking. The B.O.D. loading carried to primary settling tanks by digester supernatant return may be reduced by chlorination.

Chlorine applied to trickling filter and activated sludge processes must be controlled to prevent interference with plant efficiency. Caution must be exercised when prechlorination is practiced for odor control, to control chlorine dosage so that septicity is prevented, but not to accomplish disinfection. Many operators determine chlorine demand and adjust prechlorination units to remove one-half of the chlorine demand when treating to prevent septic conditions. Other operators report that chlorine residuals must be established in order to provide effective odor control.

Odors and ponding at trickling filter plants have been controlled by chlorination. Control of chlorination to satisfy fifty to seventy-five per cent of the chlorine demand will not adversely effect the biological growth on the filter stones, but will control odors. Filter ponding, when caused by organic accumulations, may be alleviated by chlorinating the filter influent to produce 2 to 10 ppm residual chlorine at the nozzles*. Residuals in the lower range may not upset filter operation, but for ponding control, higher residuals should be attempted intermittently, such as once a week.

Chlorination at activated sludge plants to prevent sludge bulking is predicated on the selective control of biological life in the sludge returned

*Manual of Practice No. 4, "Chlorination of Sewage and Industrial Wastes. Federation of Sewage and Ind. Wastes Assns. (1951).

Builders-Providence Photo

Fig. 3—AUTOMATIC CHLORINIZER and Chronoflo Transmitter.
Rate of flow indicated by transmitter and proportional dosage rate maintained by Chlorinizer.

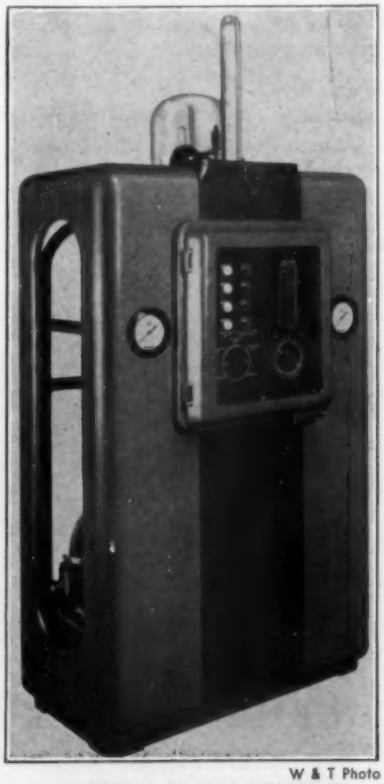

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Fig. 4—PROGRAM CHLORINATOR push button type.
Other units use cam operated control.

to primary units. Too much chlorine would have a deleterious effect on the normal biological organisms depended on to carry out the treatment process. The procedure involves intermittent application of chlorine in a controlled dosage dependent on ppm solids in the returned sludge, the rate in mgd at which sludge is returned, and on the sludge index.

Industrial Wastes Chlorination

Programs for the abatement of stream pollution have required industry to examine ways and means of controlling and treating waste discharges to prevent fouling of surface waters. Industrial wastes which respond directly to chlorination are electroplating wastes containing cyanides and chemical manufacturing wastes containing phenols. This treatment has been widely accepted since cyanides and phenols are toxic to fish life and may cause stream degradation when discharged untreated. Chlorine together with an alkali may be used to oxidize either of these compounds, provided proper pH conditions and free available chlorine residuals of sufficient magnitude are maintained during the available contact period. Chlorine dosages usually exceed the theoretical requirement due to the presence of additional oxidizable materials.

Where waste treatment plant effluent is conserved for reuse, such as irrigation or industrial process water, chlorine serves as a disinfecting agent to prevent disease transmission, in addition to oxidizing objectionable waste products.

Residual Testing Equipment

Various colorimetric procedures have been proposed for chlorine residual determination. Ortho-tolidine remains the reagent specified in Standard Methods for the Examination of Water and Sewage, and several types of commercial comparators are in use (Fig. 31). From the foregoing discussion it appears that any colorimetric method would be liable to interference from color or turbidity. The ortho-tolidine procedure does have its limitations and, while improvements have been made in the method, it falls short of the ideal technique.

If recognition is given to the limitations of the ortho-tolidine method, it may be used to make chlorine residual determinations sufficiently accurate for most purposes. Interference due to iron, manganese and nitrites may be offset by following the ortho-tolidine-arsenite (OTA) modification. When sewage contains industrial wastes of an interfering nature, the ortho-tolidine method is a poor indicator for residual chlorine.

In water purification, the breakpoint and superchlorination processes must be controlled to provide free available chlorine residuals for minimum contact perods. The ortho-tolidine-arsenite modification permits reasonably quantitative estimation of free and combined available chlorine residuals.

The Amperometric Titrator* apparently overcomes the shortcomings of the ortho-tolidine colorimetric method (Fig. 1). This instrument measures the low flow of electric current which is produced when a sample containing chlorine is titrated with a suitable reagent. Residual chlorine may be determined quantitatively, and it is possible to differentiate between free available and combined available residual chlorine by pH adjustment of the sample. The writer's experience indicates that the amperometric titrator measures more of the germicidal combined chlorine than is possible using the standard ortho-tolidine colorimetric procedure.

The Residual Recorder* represents a significant advancement in the field of sanitation (Fig. 2). This instrument provides a continuous indication of chlorine residuals and provides a permanent record of daily results. Interruptions in chlorine application and variations in chlorine demand can be announced by alarms which are available as accessories with the apparatus. Further refinements may eventually include provisions for automatically varying the application rate.

Proportional Flow Control

Trends toward instrumentation and automatic operation in industry have been evidenced in the field of sanitation. Chlorine dispensing equipment has been developed which will respond to variations in flow of the medium being chlorinated (Fig. 3). This is an important feature, one which greatly increases the efficiency of treatment and simplifies the responsibilities of operating personnel.

The operation of automatic proportioning equipment depends on pressure differentials produced when a liquid flows through a Venturi tube, orifice plate, Kennison nozzle, or Parshall flume. The differentials resulting from flow changes are transmitted to converting units which cause the chlorine dispenser to alter its dosage at a corresponding rate.

Changes in chlorine demand cannot be interpreted by automatic proportioning installations, consequently the operator must make manual adjustments to insure adequate feed of chlorine. The equipment will pace the chlorine dosage automatically proportional to liquid flow for any manual setting.

Program Control

The term "program control" is used to denote intermittent chlorine dosage according to a pre-determined schedule. Such applications include chlorination of cooling water lines for slime control and installations where pumps operate on a pre-set schedule, etc. Equipment has been developed which will permit chlorine application on an intermittent basis over a twenty-four hour period.

In program control chlorination, advance information is required so that appropriate time settings may be made to schedule chlorine dosage at a pre-selected rate over the time interval desired. Program controllers are available which operate either on a cam rotation or push button principle (Fig. 4).

Summary

Dosage control must be recognized as the foundation upon which a successful program of chlorination is built. Proper dosages for disinfection greatly exceed amounts necessary for odor control at sewage works. The amount of chlorine required to disinfect a water supply on one day (or even one hour) might fall far short of adequacy or constitute overchlorination on the following day (or hour), even though the volumes of water treated are equal.

Determinations of residual chlorine indicate whether or not sufficient chlorine has been added to establish desired conditions. Operating personnel must realize the limitations of chlorine residual test methods and, where possible, relate chlorine dosage directly to results accomplished.

Automatic devices have made substantial contributions to facilitate dosage control, but plant operators must make manual adjustments for variations in chlorine demand.

*Products of Wallace & Tiernan Co., Inc.

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If you want a truly "Never Clog Pump" specify as follows:

"Pump shall be of the non-clogging vortex type with recessed impeller mounted completely out of the flow path between pump inlet and discharge connections to enable passage of solids particles equivalent to discharge pipe diameter."*

*Taken from consultants specifications for sewage and sludge pumps.

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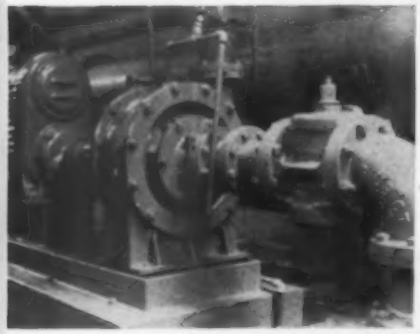
General Specifications:
Sizes: 3" through 8"
Material: Cast Iron
Capacities: 50 GPM to 2500 GPM
Heads: Up to 100'
Necessary Clearance Adjustment: None
Models: Horizontal or Vertical (Most sizes)
Drive: V-Belt, Varidrive or direct connected (Most models)



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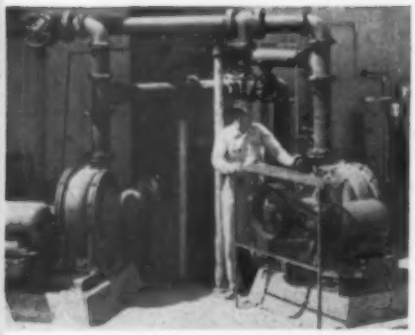
Heads: Up to 100'
Necessary Clearance Adjustment: None
Models: Horizontal or Vertical (Most sizes)
Drive: V-Belt, Varidrive or direct connected (Most models)



FOR GRIT HANDLING OR DIGESTER CLEANOUT:

Wemco Solids Pump never clogs either in continuous or intermittent operation. Long wear life and no blockage combine to provide the ultimate in overall low cost material handling.

At Los Angeles County, California

General Specifications:
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Material: Ni-Hard
Capacities: 50 GPM to 2500 GPM
Heads: Up to 100'
Necessary Clearance Adjustment: None
Model: Horizontal only
Drive: V-belt or Varidrive

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Columbus 12, Ohio,
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SLUDGE HANDLING*

THE DISPOSAL of sludge is a major problem in a sewage treatment plant. Facilities for handling sludge add to the cost of construction and operation. Problems peculiar to the handling of sludge vary according to the type of sludge being handled.

Raw sludge from primary treatment plants contains from 5 to 8 per cent solids of heterogeneous nature including coarse particles, fibrous material, grease, fine sand, trash and ground screenings (where screenings are comminuted.) Activated sludge and trickling filter sludge is relatively homogeneous, with less than 3 per cent solids and presents few hydraulic or mechanical problems in handling; trickling filter humus is similar.

Screenings and Skimmings

Problems of handling ground screenings can be reduced by using screens with openings of ¾ to 1 in. and discharging the ground screenings ahead of the screens. Coarse material leaving the grinder is caught again and reground.

Skimmings consist of all types of flotable material which will rise in a sedimentation tank. This material is frequently skimmed off to wells from which it is pumped to digesters along with the raw sludge. A major percentage of this heterogeneous material is grease which includes fats, waxes, soap and oils. In addition to these substances, skimmings also contain sticks, matches, leaves, paper, feces, soap, rags, hair, and other miscellaneous objects.

In some plants, skimmings have been sold for their grease content but this practice is not generally economically feasible. In other installations, skimmings are burned in special incinerators. Where skimmings are transferred to digestion tanks with raw sludge, the resulting problems include pumping difficulties, clogged lines and meters and scum formation in digesters.

Pumping difficulties result from the congealed character of the skimmings and their resistance to flow. This problem is overcome to some extent by introducing excess water with the skimmings in the well and ahead of the pump suction. Sludge lines handling skimmings become reduced in size and may even clog entirely due to the deposition of the grease on the inside surface of the lines.

Metering of skimmings is difficult because of the tendency of the material to deposit on the inside surfaces of the measuring devices and to clog the throat of differential producers.

Pumping Sludge

Pumps employed for raw sludge may be positive displacement piston pumps or "screw-feed" centrifugal pumps or a combination grinder and centrifugal pump. Clogless centrifugal pumps have come into use in recent years.

The choice of pump will usually consider factors of location, type of sludge, suction and discharge head, etc. Generally, raw sludge pumps are placed in pumping stations below the water level in the sedimentation tanks and therefore operate under a positive suction head. Provision must be made for a build up of pressure resulting from depositions in the discharge line. Thus rugged equipment is required. It is always desirable to have a minimum length suction pipe and as few bends as possible in the suction line.

Maintenance on sludge pumping equipment is high, wear on packing is rapid. This is especially true where the sewage comes from a combined system and contains fine grit (80 to 100 mesh). Cleanliness is a problem in sludge pumping stations caused by leaking packing, cleaning obstructions from pumps, and drawing samples.

Piping

The sizing of pipe for sludge pump discharge lines presents a problem in sludge handling. Some designers prefer small pipes to produce high scour velocities and prevent deposition in the pipe line; others prefer large pipes which give low velocities with low head loss. These pipe lines should have as few bends as possible and cleanout holes at elbows are desirable.

Where skimmings are pumped through raw sludge lines and deposition of grease occurs, cleaning may be done by steam injection to heat the water in the lines. For cast iron pipe this heating (and cooling) must be slow and controlled to prevent cracking. Temperatures of 150 to 180 deg F are desirable. The use of steel pipe for sludge lines is warranted where steam cleaning is to be used and it has been suggested that twin lines be installed so that interruption to pumping can be avoided during cleaning operations.

Metering

Because of the nature of the material being metered, and the tendency to clog, the metering device should be the simplest possible. A Venturi tube especially designed for handling the sludge and with continuous flushing systems for the pressure connections is the most practical.

Some designers do not include metering devices in sludge lines, first because of the difficulties of keeping the device clean and secondly because the nature of sludge makes it difficult to measure rate of flow. Other designers believe that a measurement of sludge pumping discharge, even if inaccurate, is desirable. It indicates whether or not pumps are operating or plugged, and it gives some indication of the amount of sludge removed in the settling tank and the loading on the digestion tanks. Both factors are important to good operation.

Miscellaneous Problems

Sampling of sludge presents difficulties, yet is essential to control of loadings on digesters as well as determining the effectiveness of sedimentation. In order to control the concentration of sludge discharged to digesters, it is necessary to sample frequently to make sure that the concentration of sludge being pumped is at the desired level. This control prevents the costly pumping of volumes of cold water into digesters.

The handling of secondary sludge is not as difficult as raw sludge; it presents few problems of pumping or clogging of lines. Sampling is required in order to control the amount of free water pumped with the sludge. In some instances, secondary sludge is thickened to reduce its water content before it is discharged to digesters or other disposal processes.

* Material for these notes was obtained from "Problems in Sludge Handling" by C. R. Velzy—*Wat. & Sew. Wks.*, Ref. & Data issue, Apr. 1948.

Controlled Humus Production

by Separate Sludge Digestion and Drying

by LEONARD L. LANGFORD

Eastern Sales Manager, Pacific Flush Tank Co. Port Chester, New York

AS BERNARD M. BARUCH has observed—"Because of the great abundance of the earth's resources we have taken them for granted." "Since our real wealth—as opposed to the product of the government printing presses—is drawn from the earth, in always limited quantities as minerals, food, wood, water and wildlife, destruction of the earth's surface, and waste of its products have a cogent meaning that touches the life, today and tomorrow, of every human being."

In his book *Road to Survival,* William Vogt states that three hundred years ago approximately half of the total area of the United States was covered with forests. "Most of our rivers ran clear . . . Salmon were so abundant in eastern rivers that indentured servants included in their articles a limitation on the numbers of times a week they should have to eat this fish."

Erosion

American civilization, founded on 9 in. of topsoil, has now lost one-third of this soil. During the past one hundred years, the Potomac River has carried more than half a billion tons of soil past Washington. Since early colonial days, erosion has removed from one-fourth to three-fourths of the best part of the crop-producing topsoil from more than five million acres of the complete Potomac River drainage basin.

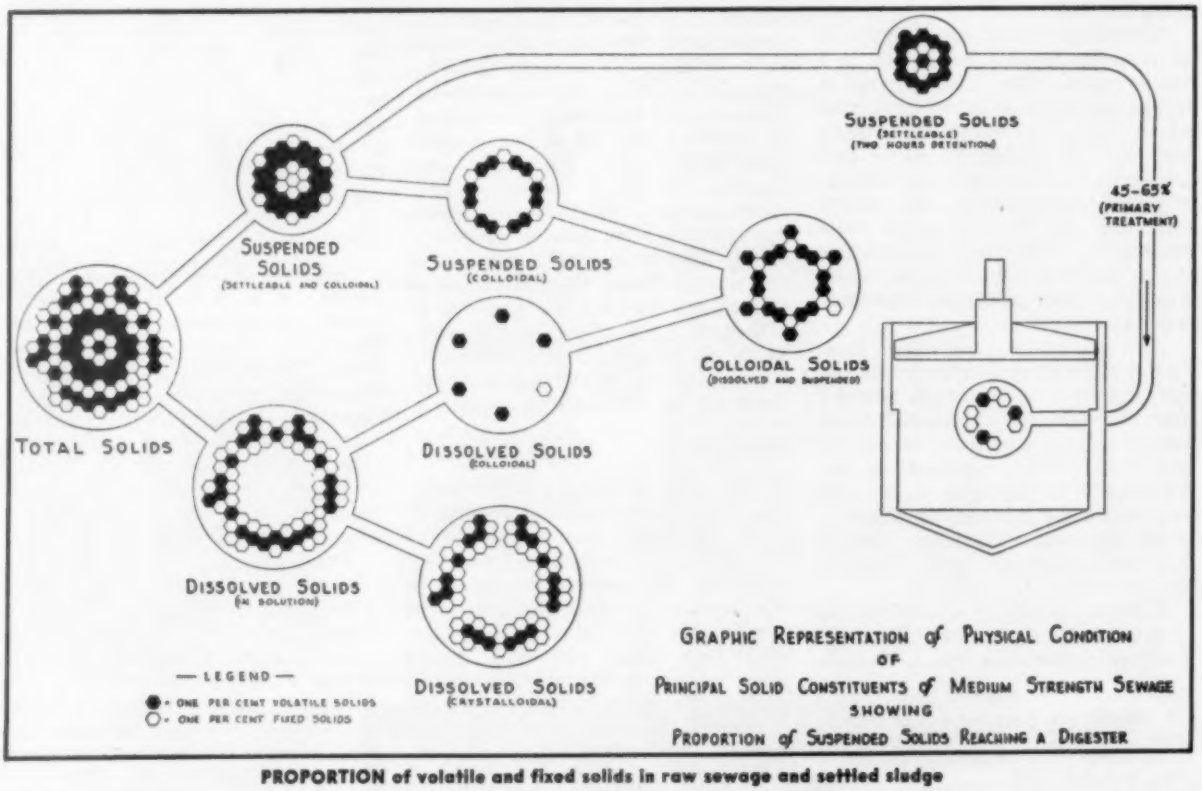
The consequences of insufficient ground cover of the right type—i.e. topsoil—are reflected in another problem "that should worry a good many Americans . . . our underground waters. Throughout much of the United States the water table is falling."[1]. In the Baltimore area, for example, presumably as a correlative of the erosion and siltation just referred to, the water table has dropped 148 feet in 32 years.

With the need for topsoil so pressing, we cannot as a nation afford to continue to throw away the valuable organic humus of digested sludge.

Principles of Manufacture

As every separate sludge digestion facility is to some degree producing tons of material, the humus value of which has largely been overlooked, why not consider the reduction of sewage-waste solids as a (biological) manufacturing process? As the result of extended bacteriological research, Bushwell has stated that we can control the process of sludge digestion by methods similar to those of other fermentation industries[2].

While the mechanical details of tanks and equipment are of importance and while chemicals occasionally play a leading role, we are completely dependent on natural biologi-



PROPORTION of volatile and fixed solids in raw sewage and settled sludge

ADMINISTRATION building and digester, Central Delaware (Pa.) sewage treatment plant

cal activity in the manufacture of an acceptable end-product which is potentially saleable as a fertilizer base.

Major problems facing those responsible for the processing of waste organic solids include:

1. Lack of adequate process facilities;
2. Interfering raw materials; and
3. Inadequate funds for Works operation and plant maintenance.

Before being able to intelligently survey any given facility and turn out an acceptable product, a Works Manager must have an understanding of the theoretical fundamentals of bacteriological decomposition of organic matter.

Theory of Digestion

1. The process of decomposition of sewage-garbage wastes involves microbial and chemical action. The former is biological, including action of bacteria, fungi, yeasts, protozoa, enzymes, etc., whereas the latter comprises hydrolysis (a chemical reaction produced by decomposition of a compound in which its elements take up water) and oxidation and reduction (the separation of an element from other elements combined with it).

2. Raw sludge is composed in part of organic constituents such as sugars, starches, cellulose and lignins. The extent of decomposition of such carbohydrates depends not only on the nature of the microorganisms, but also on the nature and amount of available nitrogen, as pointed out by Waksman.[3]

3. Digestion is dependent upon biological action of microorganisms which fortunately sewage-garbage wastes normally contain. The organisms utilize the organic matter as food supply for their growth and energy. Resulting from their metabolism, there are produced the intermediate products of sludge-liquor and methane gas, and the end-product of digested sludge, or humus.

4. The rate of digestion is influenced by environmental factors, such as temperature, reaction (pH), oxidation-reduction potential, as well as by the chemical composition of the solids.

Cognizance must be taken of the three general divisions in an anerobic digestion process, which according to Rudolfs[4] include:

(a) Intense acid production
(b) Acid regression (digestion)
(c) Intensive digestion of more resistant materials.

A fourth division might be designated as a period of decreasing gasification as digestion is completed, with an increase in pH and representing a "humification" stage.

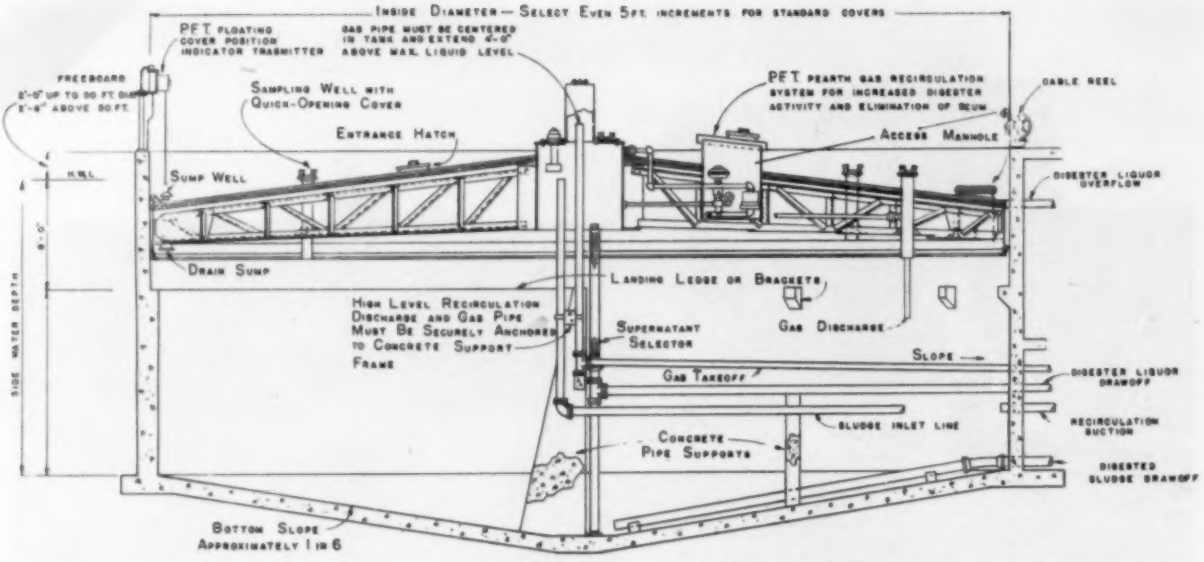
The presence of carbohydrates in any appreciable quantity accentuates the tendency towards acidity. The presence of alkaline salts as are found in hard waters or in humus-like bodies associated with well-digested sludge, serves as a buffer against the development of detrimental acidities. As the organic acids formed in the first stages of digestion are neutralized by the products of the second and third stages, activities reach an equilibrium.

In actual practice all stages of digestion are, to some extent, present simultaneously; particularly in a primary tank. Proper balance can best be maintained by the frequent addition of fresh raw solids thoroughly mixed with well buffered (digested) material. While E. B. Phelps reported digestion of 10 percent per day, yielding 90 percent digestion in 22 days and 95 percent in 28 days, current process efficiency has increased such rates materially.

Plant and Structures

The site of the sewage treatment plant, as of most manufacturing plants, is largely determined by the availability of raw material, the cost of land, and adequacy of suitable finished product disposal. Unlike most factories, whose structures and equipment must meet minimum standards of safety and production, too often the process of humus production bears little relationship to recognized efficiency and health standards. The design of tanks, machinery layout, flow of material, and automatic and safety controls is all too frequently determined by political as well as pseudo-economic considerations. Also, while plans and specifications may be adequate, the works are constructed on the basis of lowest initial cost, rather than on experience and knowledge of the peculiarities of process and equipment requirements.

When placed into operation, the works are not necessarily complete. All machinery may not have been tuned up, instruments may not have been calibrated, operation schedules and production work sheets may not have been drafted, nor maintenance schedules considered. Too often laboratory apparatus is not available during the initial operating period when


INSIDE DIAMETER — SELECT EVEN 5FT. INCREMENTS FOR STANDARD COVERS
PFT FLOATING COVER POSITION INDICATOR TRANSMITTER
GAS PIPE MUST BE CENTERED IN TANK AND EXTEND 4'-0" ABOVE MAX. LIQUID LEVEL
FREEBOARD 2'-0" UP TO 30 FT. DIA. 3'-0" ABOVE 30 FT.
SAMPLING WELL WITH QUICK-OPENING COVER
ENTRANCE HATCH
PFT PEARTH GAS RECIRCULATION SYSTEM FOR INCREASED DIGESTER ACTIVITY AND ELIMINATION OF SCUM
CABLE REEL
ACCESS MANHOLE
DIGESTER LIQUOR OVERFLOW
H.W.L.
SIDE WATER DEPTH
SUMP WELL
DRAIN SUMP
LANDING LEDGE OR BRACKETS
HIGH LEVEL RECIRCULATION DISCHARGE AND GAS PIPE MUST BE SECURELY ANCHORED TO CONCRETE SUPPORT FRAME
SUPERNATANT SELECTOR
GAS DISCHARGE
SLOPE
GAS TAKEOFF
DIGESTER LIQUOR DRAWOFF
SLUDGE INLET LINE
RECIRCULATION SUCTION
CONCRETE PIPE SUPPORTS
DIGESTED SLUDGE DRAWOFF
BOTTOM SLOPE APPROXIMATELY 1 IN 6

GENERAL details of floating cover digester showing interior piping and "Pearth" gas recirculation system

it is so greatly needed, particularly such items as a Pang Sampler and a Hellige electronic pH-Meter.

Unfortunately, months and oftimes years elapse before the Works Manage can prevail upon the (sewer) Board of Directors for funds which must be made available for required small tools, replacement pipe fittings, supplemental lighting and electric power outlets, hose and fittings, portable pumps, grease and oil, cleaning utensils, ladders and rope. The immediate availability of fire extinguishers, oxygen masks, safety harness and other items of industrial safety equipment might prevent an injury or save a life.

Reconstructions of such parts of structures, piping or machinery, the original design or construction of which proves to be inadequate, inefficient or hazardous, should be undertaken as soon as possible. Equipment which is inaccessible for safe servicing can usually be relocated. Where process efficiency is impaired as the result of pumps which are improper in capacity or head characteristics, or in location, or in method of piping connections, management should make suitable changes promptly. The relocation of a valve, or addition of a valved cross-connection in sludge piping might enhance operating efficiency several-fold. Installation of vacuum and pressure gauges at sludge pumps, of ammeters located in pump motor circuits, recording thermometers for registering top-sludge temperatures, supplemental gas pressure gauges, sludge level indicators equipped with high and low level alarms, pays dividends in process economy. Additional points of back-flushing of sludge piping can result in the saving of many man hours per year. All too frequently, means for observing and for sampling raw material pumped into a digester are either lacking or inadequate, as are means for adding chemicals, when required.

The Raw Materials

Unlike most other manufacturing plants, in the production of humus from municipal sewage-garbage solids, the Works must adapt itself to handling a very uneven delivery of raw material. Its variation in quality and quantity on an hourly, daily and seasonal basis demands the utmost flexibility in plant and process facilities, together with conscientious adaptability of supervisory personnel. This raw material may be primary, intermediate, waste activated, or secondary sludge, or a mixture of any of them. It is the settleable portion of the suspended solids in the raw sewage which is to be converted into an inoffensive humus.

When it is known or suspected that industrial waste is being received, the following check list can be used to determine its characteristics:[5]

1. Volume variation—daily, hourly or seasonally
2. Chemical composition—biological, mineral, organic
3. Physical composition—color, oil, sediment, temperature, etc.

It is important that these solids be in as fresh a condition as possible. Use of fresh solids will "automatically increase process efficiency and reduce costs" according to Hood[6], who further points out that, "When the pH-alkalinity value of a sewage compares closely to that of the water supply (of which it is constituted) then the sewage is necessarily in a fresh condition". Stale solids are difficult to withdraw as the result of their initial decomposition within the sedimentation tanks, or earlier. The extent to which this condition may progress may be influenced by:

(a) the type, extent and condition of the collection system

(b) the rate of sewage flow

(c) the temperature of the sewage

The more the rate of transfer of raw sludge to the digester agrees with the rate of settling in the sedimentation unit, the more efficient will be the operation of both units! This involves as nearly continuous transfer as is practicable, preferably by means of time-clock operation of a displacement pump.

If sludge pumps are located below grade, be certain that there is adequate ventilation with all doors and windows tightly shut. Plant personnel should be acquainted with the Federation's Manual of Practice No. 1.[7]

Raw sludge, preferably preheated and inoculated, should be introduced within the digester near the center of the tank and adjacent to the gas dome area. Volume of raw sludge input, as determined by the sludge level indicator, should be noted on the daily operating log.

Discharge or sludge-liquor of optimum temperature, containing great numbers of virile organisms of suitable types within the general area of the gas dome in sufficient quantity to maintain adequate digester temperature, will prevent top-sludge ac-

INTERIOR of modern sludge control building, Levittown, Pa.

cumulation of consequence at a number of Works.

Means should be provided for controlled, observable withdraw of supernatant liquor. The nearly continuous removal of such liquor is generally desirable because of the space it requires, as well as its effect upon the material into which it is discharged. Beneficial use can frequently be made of supernatant or sludge-liquor, in connection with oxidation of settled sewage.[8]

While heavy bottom-sludge should not be agitated immediately prior to transfer to succeeding process units, it can be used to advantage by mixing with less digested solids.

To assist with disrobing low specific gravity substances of their adhering gas particles, and concomitantly to increase the rate of volatile solids decomposition, the introduction of compressed gas at multiple points within the sludge-liquor zone is economically effective.

When raw sludge is seriously deficient in one or more of the minerals essential to the maximum rate of bacterial metabolism, the addition of suitable chemicals may be desirable to correct such a nutritive imbalance. Lime, however, should be used with discretion, as an excess might result in the retardation of microbial activity. The use of aluminum sulfate or sodium nitrate might prove beneficial for a purpose of reaction (pH) control.

Starting a Digester

The starting of a digester should be carried out with due regard to the safety of personnel and structures, as follows:

(a) Fill the tank with fresh sewage as fast as possible, to the minimum volume required to evacuate all air within the confined structure.

(b) Raise the temperature of the sewage (or water) to between 80°-85° F, using auxiliary fuel if required.

(c) Then, and not until then, introduce not more than about three percent of the occupied volume with preheated, *fresh* raw sludge in two or more daily increments.

(d) Maintain continuous control of digester temperature by raising it about five degrees in the following thirty days.

(e) Withdraw supernatant liquor continuously at a low, controlled rate—about two percent of the occupied volume per day.

(f) Do not allow the pH to drop below 6.5 or 6.3.

Digester Operation

Maintain a close check on conditions within all digesters at all times. While use of pH and alkalinity are usual indices, volatile acids, oxidation-reduction potential and CO_2 content of the gas produced are all more sensitive control methods, if means are available for making them.

The portion of any tank in which primary digestion is to take place should resemble an ebullient cauldron, in continuous ferment. However, only mild ebullition is all that can be expected through the gas produced as a natural result of the metabolism of the organisms. This, then, should be supplemented by more or less continuous recirculation of the tank contents. Controlled degradation of the organic material by an orderly vertical progression of reduced volatile solids is of the utmost importance, particularly in the secondary or tertiary stages of the process.

Temperature plays a very important role in the rate of volatile solids digestion; it should be maintained within a degree either side of 97° F. throughout the upper two-thirds of a primary unit, if the oils, fats, and waxes normally present are to be acted upon.

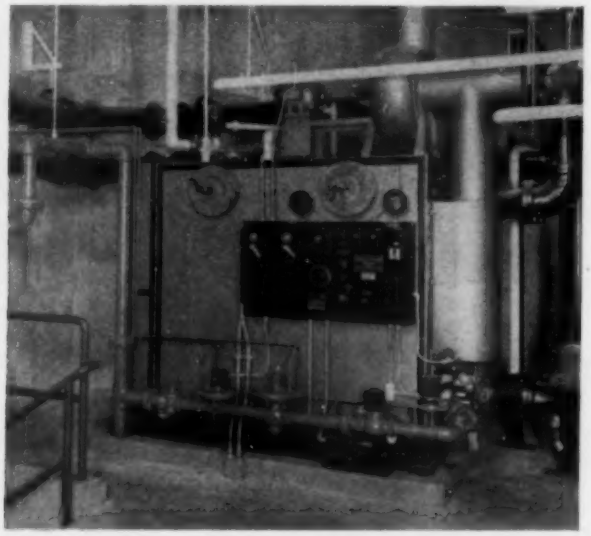
With intensive controlled digestion, the rate of gas evolution increases rapidly to a maximum within three hours after completion of a charge of raw material. Forty percent of the final volume of gas may be produced in the first twenty-four hours, with ninety percent within six days.[9]

Gas collection, measurement, storage, use and wasting should be carried out under conditions which will insure safety to personnel and structures. This involves adhering to the principle of continuous and positive pressure (at least 1″ water column)

P.F.T. equipment and methods for modern waste treatment

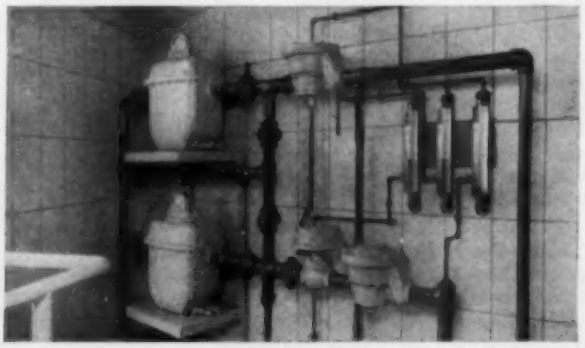
Cities and industries of all sizes have used PFT equipment and processes for effective waste treatment since 1893. Whether extending capacities, converting to newer methods or installing new systems, PFT equipment is economically adaptable to existing structures. Suitable to all current waste treatment systems, PFT equipment ranges from the smallest siphon to the largest municipal installations. PFT stands squarely behind its products and provides expert *field service* as long as its equipment remains in use.

Floating Covers—An integral part of "controlled" digestion, PFT Floating Covers provide positive scum submergence and safe utilization of gas. Operations are simplified because no fixed levels need be maintained. Covers simply rise or lower with additions and withdrawals. Available in different shapes and sizes for various tank requirements. Complete data on properly sized covers furnished on request. Submit the total digester volume required and number of digesters contemplated.



Digester Heaters and Heat Exchangers—External heaters for digestion tanks allow complete accessibility in a compact unit of high thermal efficiency. Raw sludge or a mixture of raw and recirculated digester contents is heated as it passes through the unit. With external heating, the problems of heating coils within the tanks (caking, corrosion) are avoided. Cleaning and maintenance are simplified. Detailed drawings and estimated digester heating loads furnished on request. Submit the number of digesters, tank capacities and quantity of raw sludge.

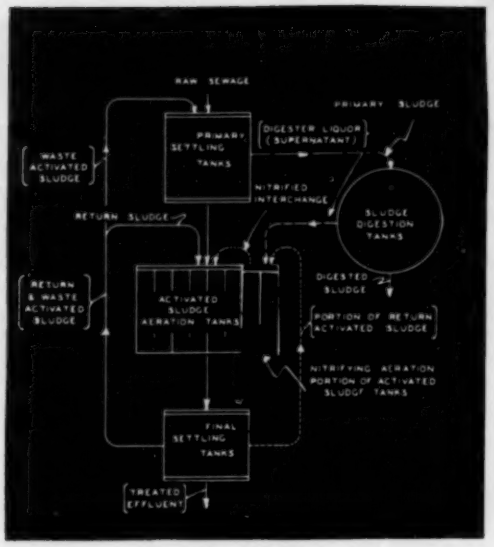
Prefabricated Metal Roofing—This type of roofing provides four distinct advantages over conventional wood types: (1) longer life, (2) more efficient insulation, (3) fewer maintenance problems, (4) easier assembly and installation. Each prefabricated section is designed for close fitting in the field with a 3″ lap of top metal covering at all joints.

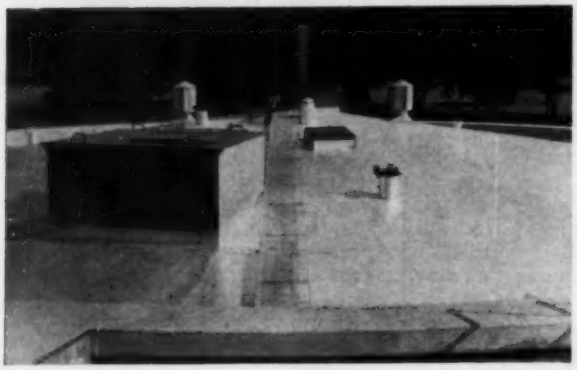


Gas Safety Equipment—A number of devices, each designed to perform its function in a gas utilization system with the greatest possible protection against explosive or burning mixtures of sludge gas and air: flame traps, pressure reliefs, pressure reliefs combined with flame traps, flame cells, waste gas burners, drip taps, accumulators and manometers.

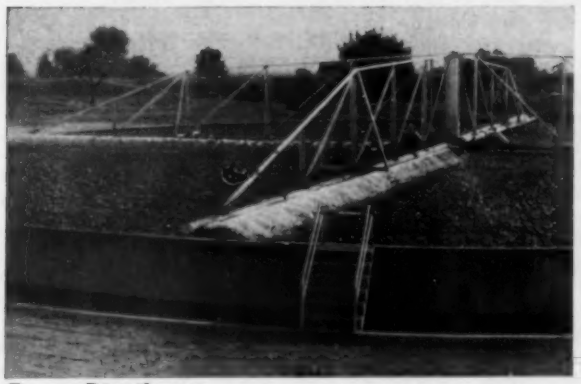
Kraus Interchange Process—A process of aerating waste activated sludge, utilizing the digester supernatant liquor to produce highly nitrified solids that: (1) During *normal* loads, produce sludge that settles more readily to provide greater purification. (2) During *peak* loads, provide a reserve of highly nitrified active solids which balance the increased load of organic matter. A truly "controlled" activated sludge process.

Kraus Distributed Air Process—A new method of introducing air into aeration tanks. Combined with the Kraus Interchange Process, it provides: (1) Greater Stability of activated sludge treatment, (2) More efficient treatment of shock loads, (3) More efficient use of aeration tank capacity, (4) Lowered power requirements for air.

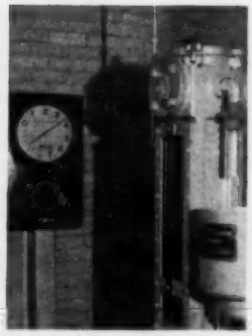




Pearth Gas Recirculation System—An effective method of increasing dispersion and digestion of scum, allowing full effective use of total digester volume at all times. Designed as an integral part of the PFT Floating Cover, the Pearth system breaks up the scum and releases entrained gas by recirculating digester gas and discharging below the scum level. Complete data on the Pearth Gas system on request. Submit digester volume, diameter and number of digestion tanks.



Rotary Distributors—Soundly engineered and ruggedly constructed, PFT Distributors provide even distribution of settled sewage over the surface of a trickling filter. Specially designed spreader jets reduce clogging and are easily cleaned. For hydraulic design of equipment, submit diameter of filter bed, total head available, maximum and minimum flows desired.



Digester Accessories—The PFT Supernatant Selector, Gauge, Sight Glass and Sampler units provide automatic withdrawal of the best digester liquor at a slow, continuous rate. The PFT Cover Position Indicator reflects the slightest Floating Cover movement on a large dial in the Control Room, showing digester liquid level at a glance.

Illustrated Bulletins—Detailed information on PFT equipment is available in a series of technical bulletins, fully illustrated with photographs and diagrams. Please specify the equipment in which you are interested. Address all inquiries to Dept. RD, Pacific Flush Tank Company.

Technical Studies Available—The following studies are available without charge: "*A Rugged Activated Sludge Process*", by L. S. Kraus; "*Scum Control in Sludge Digestion*", by R. E. Fuhrman; "*What You Should Know About Sludge Digestion*", by H. E. Schlenz; "*Controlled Humus Production*", by L. L. Langford.

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MODERN laboratory of sewage treatment plant at Arlington County, Va.

in all parts of the system—at all times![10] For each cubic foot of sewage gas consumed, about six and one half cubic feet of air are required for combustion. Therefore, fresh air inlets should be of adequate capacity and preferably so positioned as to minimize undesirable drafts through interconnecting rooms or corridors. Periodic inspection and preventive maintenance schedules should be established for gas utilization apparatus. This is just good common sense!

Together with adequate lubrication, painting is perhaps the most important function to be carried out in connection with maintenance of machinery and structures. Determine the proper types of grease and oil, and use them skillfully.

Readily available adequate records of operation are frequently invaluable when difficulties arise. In addition to data required by governing authorities, it is well to keep posted on the contributing population-equivalent in terms of solids, in both the raw feed and final product, and the indirect effect of the weather as reflected in gas production, etc.

Laboratory Tests

The extent of records relating to sludge digestion will depend to some degree upon the amount of laboratory work which is done with regularity. Such work should include daily, weekly and monthly determinations. Just what these determinations are to be must be dictated by the requirements of governing bodies, and the dictates of one's conscience and interest in research.

With respect to proper operation of digesters, Hatfield[11] suggests the following tests:

1. pH—a rapid and easy test of sludge acidity
2. Volatile acids—of great value where the digester is overloaded
3. Solids test—total, volatile and ash, for determining the extent of digestion
4. Digestion gas analysis—indicating abnormally high carbon dioxide and the heat value of the gas.

Safety Equipment

In sewage treatment plants, as in any industrial plant, protection against toxic gas vapors, dust or oxygen deficiencies, should be taken for granted. Unfortunately, those responsible for the design and management of sewage works have not generally been as conscientious in maintaining safety standards as have the authorities in industry.

It cannot be emphasized too strongly that the chief danger at any sewage works lies in a lack of oxygen.[7] Every portion of the plant must be adequately ventilated, even when doors and windows are closed. Minimum essential safety equipment should include masks for emergency respiratory protection, and one or more indicators for testing the toxicity or explosibility of the atmosphere.

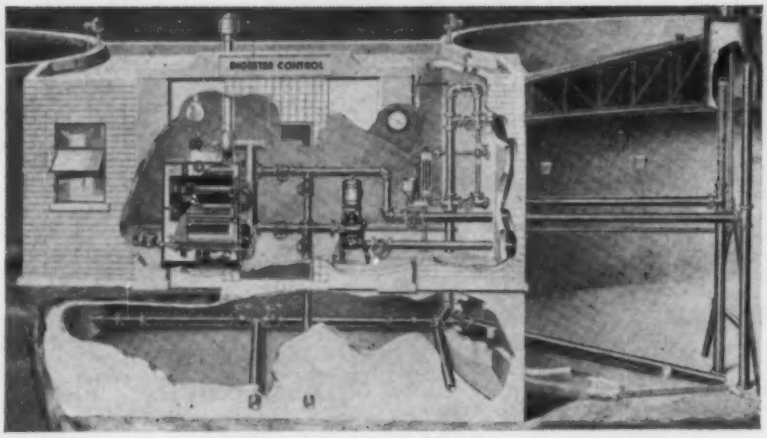
Conditioning The Final Product

From twenty to forty days after the start of controlled processing of raw sludge, a liquid humus, dark in color, and having a so-called "tarry" odor, may be in suitable condition for agricultural use. The characteristics of the processed raw material at this point are as variable as were the characteristics of the raw sludge.

Assuming that the grease content is not excessive, this liquid humus is ideal for direct application upon arable farm land. It is readily transported by tanks, for direct application to the land. When there are no large farm areas in the immediate vicinity, or when for some other reason the use of humus in liquid form is impractical, dewatering is normally the next step. This may be accomplished by gravitational filtration and natural evaporation on sand drying beds, or by mechanical filtration and heat drying.

For the average small sewage treatment plant, open or covered sand filters have been effectively used. The ability of the filter sand to carry off drainage is a most important factor. Some sands have a tendency to pack, thus resisting the free flow of water. Sand having an effective size of 0.3 to 0.5 mm, and a uniformity coefficient less than 5, is commonly specified. Sand bed drying of sludge involves draining, followed by evaporation. The rate of evaporation depends upon the difference in the moisture content of the sludge and of the surrounding air, the velocity of the air over the bed, and the temperature. Where the climate is frequently cold or damp, glass-enclosed beds provide a means of process control by acting as a rain shed and by providing control of ventilation.

It is important to properly prepare the sand surface before applying the liquid sludge, by leveling it in such fashion as will aid the flow of sludge to the far side of the bed. In other words, slope the sand surface downward from the sludge inlet. Be sure that sand is suitably banked up against all removable division boards or gates. Whenever sand has been



PHANTOM view—Controls for a "Controlled Digestion" system

lost to a depth of three or four inches, it should be replaced with sand of suitable quality.

Individual beds are frequently constructed too large. They can often be reduced in area by using suitable wood or concrete planking. Redesign with respect to relocation of truckways is commonly called for. The use of an inclined, portable, powered conveyor belt will save hundreds of man-hours per year.

In his excellent paper, "Measurement of Sludge Drying Bed Performance," Haseltine[12] suggests a method whereby sludge drying bed performance can be measured and compared. He indicates the relationship of temperature and the solid content of the material to be dried as important variables, when assessing the efficiency of air drying. He further points out that the optimum depth of application of sludge for any given plant might prove to be only nine inches on open beds, but twelve to fourteen inches on covered beds. The amount of grit in the digested sludge is also referred to as a factor in the operation of sludge beds.

Vacuum Filtration of Sludge

If the final product of digestion is to be dried for use as fertilizer base or compost ingredient, its moisture content is frequently reduced by means of a vacuum filter rather than by sand drying beds.

A vacuum filter usually consists of a horizontal steel drum, supported over a vat in such fashion that about 25 per cent of the drum dips into the metal vat as it continuously revolves. To circumvent the necessity of cleaning or replacing the filter cloth, some types of filters now use coil springs of 0.410 inches in diameter. A vacuum is maintained for a large part of a revolution. Dewatered sludge cake is scraped from the filter cloth, or the flexing of the springs as they leave the vat and pass over aligning rolls aids in the discharge of a sludge cake, the moisture content of which depends upon the degree to which it has been digested and the efficiency of the chemical preconditioning, prior to its being subjected to the action of the vacuum filter.

While economy in the cost of conditioning agents can be effected by elutriation, or washing of sludge prior to filtration, in increase in the cost of filter equipment must be recorganic materials. Besides providing ferric chloride will, of course, more than pay for the increased capital investment required to afford protection against the more corrosive material to be filtered which results from the use of this process. Elutriation conditions the sludge by reducing excessive amounts of soluble ammonia derivatives and ammonia compounds which normally inhibit coagulation. This is accomplished by successive decantations with sewage effluent or fresh water. Countercurrent elutriation is frequently advantageously used.

Summary

As the end-product of the process of sludge digestion and in addition to its use as a fertilizer ingredient, sludge humus is of great value as a soil conditioner.

Most authorities agree that organic matter is essential in soil for fertility. Humus, which Sauchelli[13] defines as organic material which has passed through the active stages of decay and is nearing complete decomposition, can be used to restore soil fertility, particularly when such humus is fortified with phosphate rock (*not* super-phosphate), cottonseed meal, castor pomace or other suitable organic materials. Besides providing certain of the elements needed for plant growth humus increases the water-holding and erosion-resisting capacity of the soil and improves its tilth, enabling heavy clay soils to be cultivated.[14] In addition, as pointed out by Imhoff and Fair[15], it furnishes a substrate for useful soil bacteria.

The value of sewage sludge as humus depends upon the extent of treatment and upon local conditions. Since, as Waksman states, "humus formation results from the decomposition of plant and animal bodies, mainly through the agency of micro-organisms . . . and is synonymous with stabilization of plant and animal residues"[16], it can readily be seen that well-digested sludge in as stable condition as possbile represents a most useful product.

Liquid sludge from digesters must be used with care, as it may contain pathogenic organisms, depending on its age. In its wet form, sludge cannot be easily transported and must therefore be used relatively near to the sewage treatment plant. On the other hand, dewatered or air-dried digested sludge is practically odorless, more easily handled and stored, and safer from a health standpoint, than liquid sludge. Both wet and dried sludge should be applied to the soil in accordance with the best practice for manure, either in the form of compost material or as a sheat mulch, and plowed under as soon as practicable after distribution.[17]

Generally speaking, the sale of even high-grade sludge as humus cannot be expected to yield a profit; however, under the right conditions, it can help to offset the cost of operating the treatment works. For guaranteed disposal of air or heat dried sludge at a fee, some consideration should be given to proper packaging, in order to assure prompt disposal against such competing materials as bulk or baled peat, humus soil, leaf mold or manure. Lumps in the sludge should be broken down with a disintegrator or hammermill, and the material piled under cover in bulk or packaged form, for convenient loading.

It is suggested that sewage plant operators can accomplish much towards increasing the demand for sewage sludge as fertilizer and humus, establish public interest in their profession and their plants, as well as enhance the morale of participating personnel. In the words of Dr. Firman E. Bear, Chairman of the Soils Department of Rutgers University, "We should lend assistance to the efforts that are designed to avoid waste of organic materials."[18] As members of the Federation, we are in a position of being able to pan great

quantities of "black gold", to the benefit of the Nation—let us work our claim safely and efficiently!

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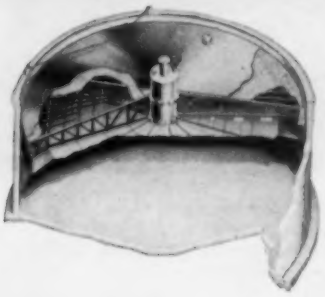

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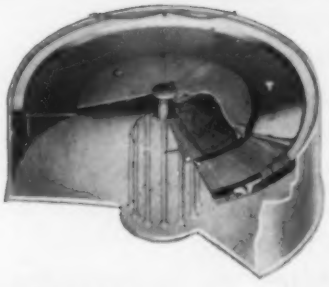

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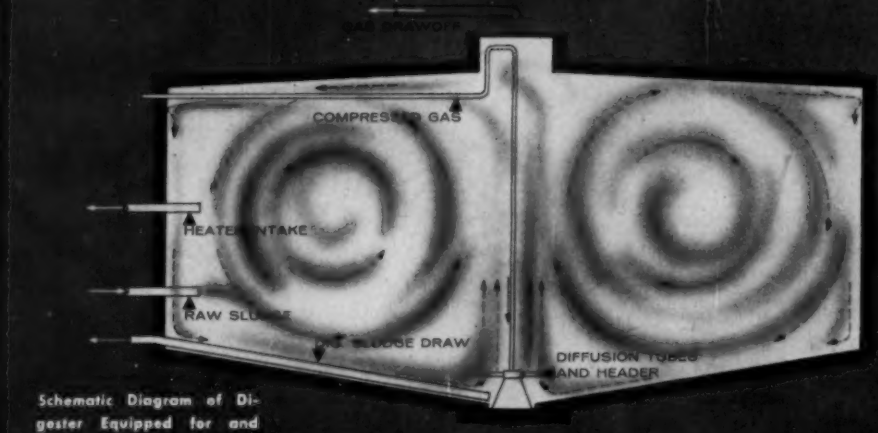

Schematic Diagram of Digester Equipped for and Operation Under CATALYTIC REDUCTION PROCESS.

RESULTS IN:

1. Smaller tanks.
2. 1/3 to 1/7 of former digester volume for biological requirements of sludge digestion† (Contrasted to actual requirements of former methods of digestion).
3. Non-formation of dense floating solids, termed "scum", eliminating former pro-ration of digester volumes for holding "scum".
4. Consistently highest degree of volatile solids reduction and gas production —through fundamental application of a simple gas diffusion mechanism— with lowest tank volume and simplified piping (as illustrated above), without increase in operation supervision requirements.

†*Exclusive of sludge storage volume that may be required by subsequent disposal methods.*

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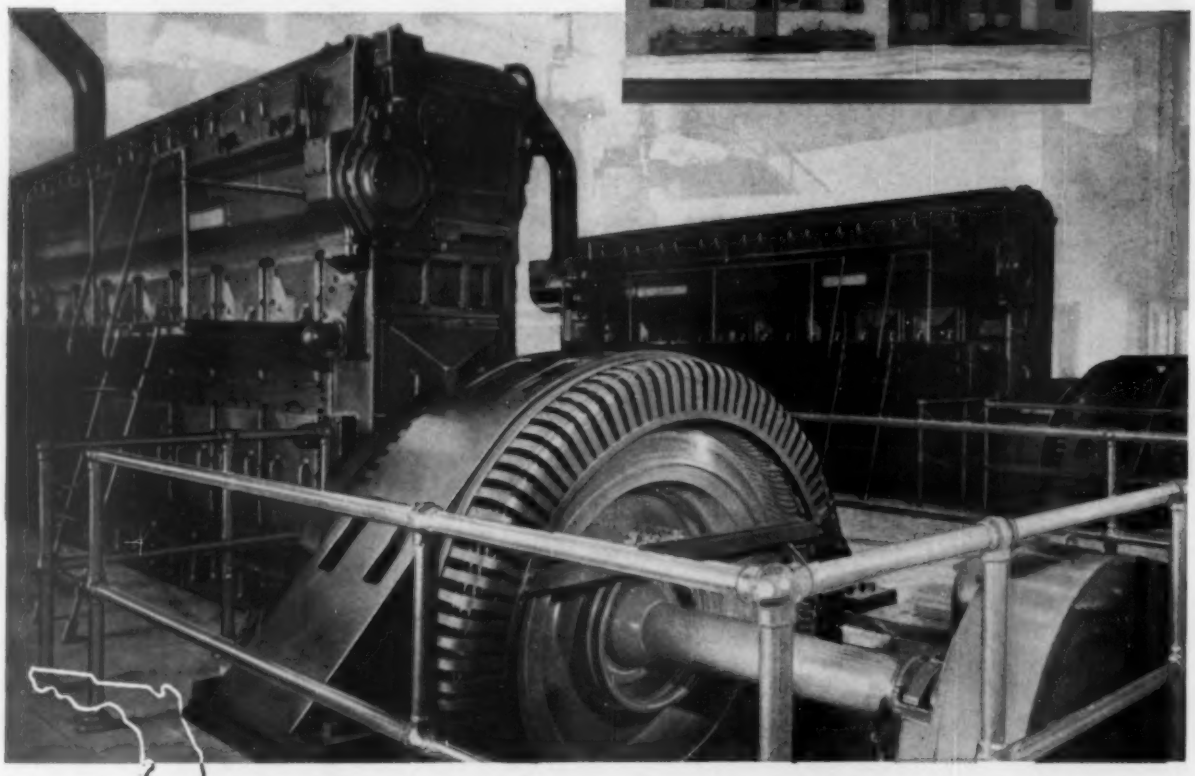

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Economical operation on low cost heavy fuel results from Superior's highly developed open chamber combustion system plus special equipment and techniques perfected by White Diesel engineers. Rugged, heavy duty construction and high quality features enable Superiors to operate with minimum maintenance even where mushrooming local demand calls for peak output.

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Dual-Fuel Engine Operating and Maintenance Experience

At New York City's Owls Head Sewage Treatment Plant and Pollution Control Project

by NATHAN I. KASS and FORTUNATO H.A. LINO

Chief of the Bureau of Sewage Disposal Operations, N. Y. City Dept. of Public Works.

Superintendent, and Owls Head Sewage Treatment Plant.

THE OWLS HEAD Sewage Treatment Plant and Pollution Control Project, with a designed capacity of 160 M. G. D. dry weather sewage flow, was designed for, and employs the high rate activated sludge process. It was designed by and constructed under the supervision of engineers of the New York City Department of Public Works. Frederick H. Zurmuhlen, P.E., R.A., is Commissioner of Public Works, and William A. O'Leary, is Director of the Division of Sewage Disposal, Dept. of Public Works.

Incorporated in the design is the plant's freedom from public utilities for operating power; no provisions for utility stand-by had been made nor contemplated for the operation of the plant equipment, all of which is electric motor driven. These motors range in size from 700 H.P. units used on the four centrifugal air blowers and on two of the main sewage pumps, down to the 1/2 H.P. units used on the sludge collectors.

To meet the full load requirements of the plant, the following equipment was to be installed: six dual-fuel engines, each of 1300 B.H.P., direct connected to 1125 KVA, 4160 V, 900 KW (at 80% power factor) generators, with direct connected exciters.

In order that all the major engine maufacturers could compete for this installation, bids were accepted on two proposals: (1)-naturally aspirated engines and (2) supercharged engines.

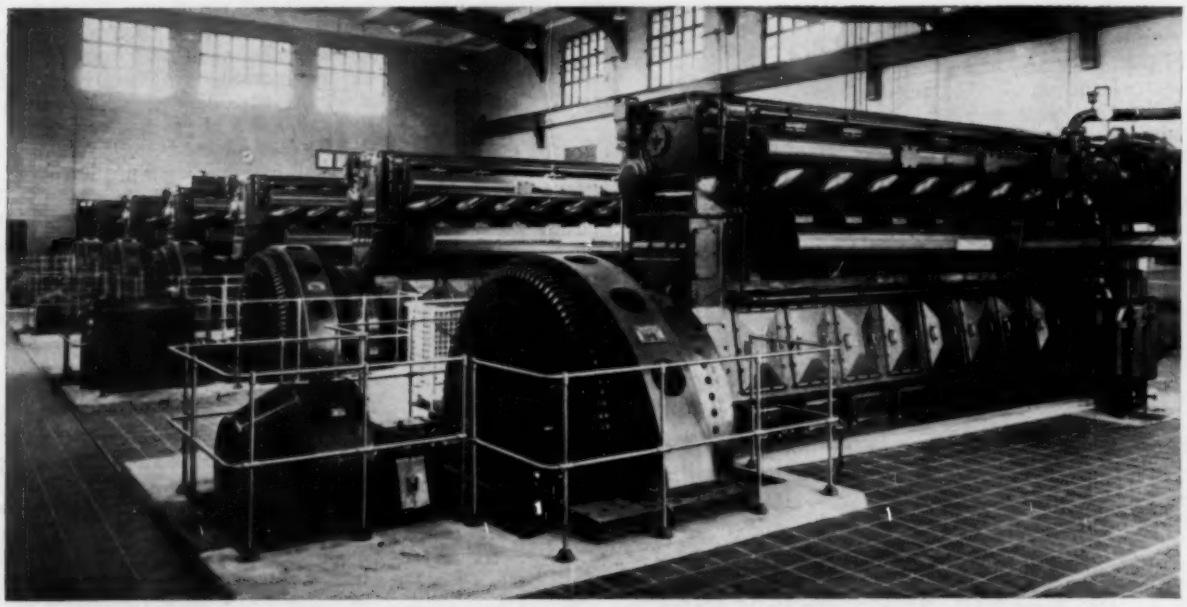
Dual-fuel supercharged "Superior" engines were selected on a basis of a bid by their manufacturer, then the National Supply Company. The White Diesel Engine Division of the White Motor Company has since become the manufacturer of "Superior" Diesels. The six engines installed are 8 cylinder, 14-½ inch bore x 20 inch stroke.

The gradual assignment of the plant's operating personnel started November 1, 1951, about four months before treatment of sewage actually began. By then, the engine installation had been completed and the units had received considerable "no load" running time.

As soon as the operating personnel acquainted itself with the generating units, a series of actual load tests were commenced.

Early Difficulties

Difficulty was encountered with some of the alarm and protective devices. All but two of these troubles were quickly rectified. The exceptions



ENGINE BATTERY—Six "Superior", turbocharged, 1300 bhp. 327 rpm dual-fuel 8 cylinder diesels drive Westinghouse 1125 KVA generators as the sole power source of the Plant.

took considerably more time due to the difficulty in localizing the faults and the work involved in making the necessary relay relocation.

The first trouble manifested itself in that the engine on test developed the defect of shutting down with no indication as to the cause.

Each of the protective devices and relays were bench tested and were found to be in good operating condition. The control wiring was checked and found to be clear.

After numerous observations and tests, it was ascertained that the centrifugal overspeed relay on the engine was at fault.The manufacturer's representatives agreed and arranged testing of the relay in their laboratories, where the device could be instrument tested under simulated field conditions. It was found that the original washer was causing false operations of the device due to its resilient construction. These operations were of such short duration that the relay that would have indicated the operation of the overspeed device, could not be picked up sufficiently to "hold-in".

This situation was corrected by using a heavier and less resilient washer between flanges; and the relay was returned to the Owls Head Plant. Five other similar washers were included, with instructions that they be used as replacements for the original washers in the overspeed relays of the other five engines: This was done.

A re-occurrence of the defect mentioned took place about three years later. Renewing of the washers eliminated the trouble.

It was found, on close inspection of the removed washers, that the pin holes in them had become only slightly elongated, yet this wear was enough to cause a "backlash" operation of the device.

The other difficulty of note was the failure of some of the engine-mounted relays to hold-in while the engine was in operation. The construction of the relays, both electrically and mechanically, was such that the normal engine vibration would cause the contacts to arc and finally open, thus causing false engine alarms and shut-downs. Relocation off the engine and better constructed relays overcame this source of trouble.

Maintenance Policy Established Early

After several conferences, before the plant was placed in operation, a policy regarding the maintenance of the engines was established.

One of the principal points agreed upon was that only small repairs, that could not possibly change any engine adjustments, were to be made by the operating force. All other mechanical work required for the proper operation and maintenance of the engines were to be performed by mechanics working out of the engine maintenance group, serving all plants in the Bureau of Sewage Disposal Operation.

Some of the other items agreed upon, were:

(a)—Oil centrifuging (when on batch process) was to be done on a 500 running hour schedule.

(b)—Oil filter replacements on a 2000 hour basis.

(c)—Valve overhaul every 4000 hours.

(d)—Complete engine inspection on a 12,000 running hour schedule.

(e)—Crankcase inspection on a 2000 running hour basis.

This understanding, between the operating staff and the engine maintenance group as to their respective functions has returned dividends in reduced enforced engine shutdowns and in lowered maintenance costs.

Treatment of sewage was started on February 19, 1952 with the engines operating as full diesels. By April 15th, digester gas in sufficient quantity and of satisfactory quality was available, and adjustment for dual-fuel operation of the engines was begun. Final adjustments were completed October, 1952.

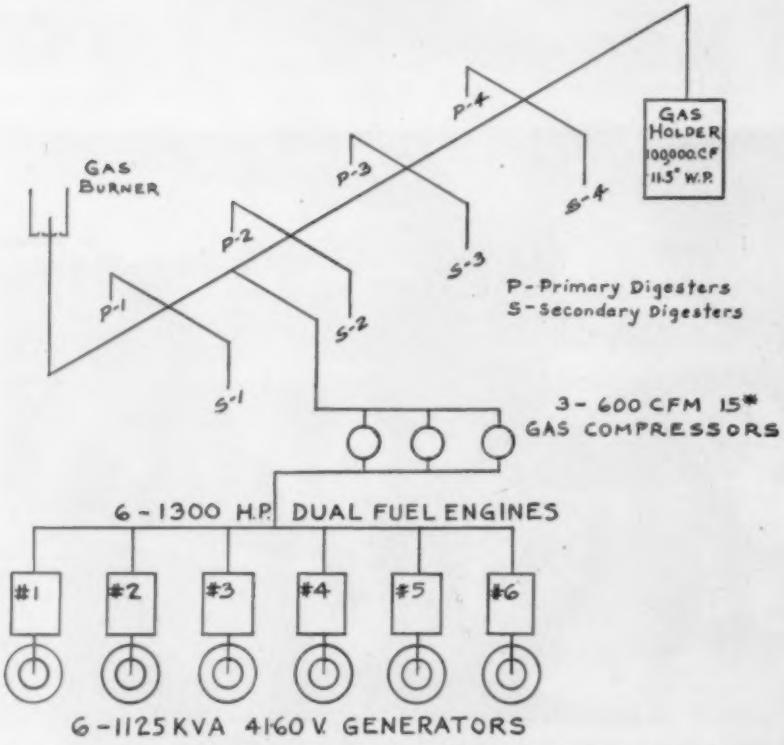
Fuel Oil Costs

During the initial period, namely, from February 19 to April 15, 1,394,000 KWH were generated at a fuel oil cost of $0.0077 per KWH. From April 15 to December 31, 1952 10,988,000 KWH were generated at a fuel cost of $0.0018 per KWH.

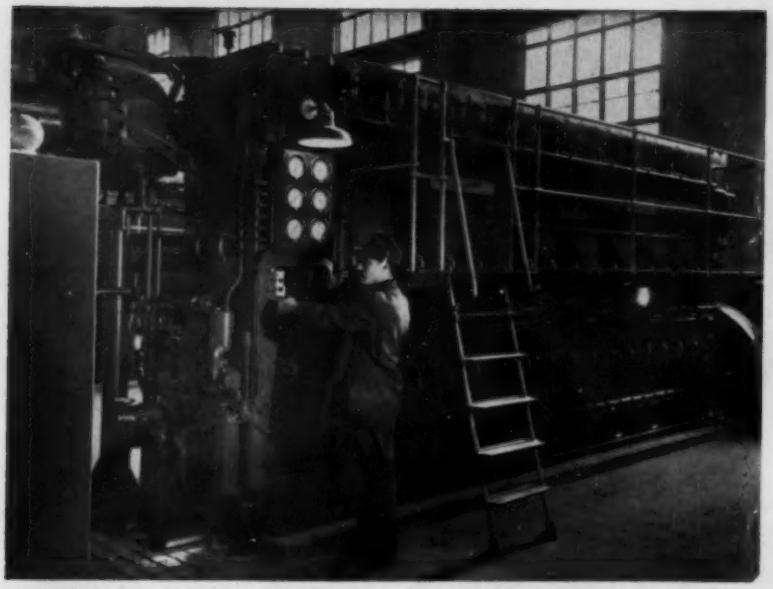
From January 1, 1953 to December 31, 1955, a three year period with full dual-fuel operations, the cost of fuel oil used for all engine purposes has average only $0.0009 per KWH. In that period, the plant generated a total of 46,100,000 or approximately 42,000 KWH per day.

The fuel oil consumption prior to the dual-fuel operation of the engine: had reached 3,000 gallons of No.2 diesel oil per day. Since stabilized dual-fuel operation of the engines was achieved, the daily consumption of fuel oil for the three year period has averaged approximately 380 gallons per day. This figure includes pilot fuel used during warm-up periods, engine testing and "run-ins". Also included in the 380 gallons is fuel oil used when enforced full diesel operation of the engines was made necessary due to gas compressor failures and to reduced gas supply. The gas compressors are used as boosters, in order to increase the digester gas header pressure from 11-½ inches of water to 15 psi at the engine.

The reduction in fuel oil consumption during the three year period from



SCHEMATIC sketch of gas system from digesters to gas storage, to gas pressure boosters, to engines driving generators



STARTING one of the "Superior" diesels is accomplished on diesel fuel. Then, upper push button throws engine over to automatic dual-fuel (gas & diesel fuel) operation.

January 1, 1953 to December 31, 1955 because of dual-fuel operation as compared with full diesel operation represents an annual saving of approximately $105,000, at fuel oil costs, that varied from 10.1 cents to 10.5 cents per gallon.

One of the requirements of the engine contract was that the engines go from dual-fuel to full diesel operation and still maintain parallel operation, this with control changes in fuel proportions. From the numerous gas compressor failures, with accompanying sudden reduction in gas pressure, it was found that the quick manual dropping of load helped to keep the generators on line while the engines, through the governors, adjusted themselves to the change in fuel proportions.

Gas Production Adequate

From April 16, 1952, when the use of gas began, to December 31, 1955, approximately 930,000,000 cubic feet of gas, with a B.T.U. value averaging about 650 per cubic foot, have been used in the engines. Gas production has normally averaged far in excess of the quantities needed to operate the engines and to fuel the boilers for space and digester heating. This average has been estimated in excess of 900,000 cubic feet per day. There have been times, such as following heavy rainstorms, when gas production has not fully met the demand.

For the present dry weather flow, averaging 85 M.G.D., three generating units are operated in parallel for the period 8 A.M. to midnight, after which two unit operation is practiced. The units are normally operated at about 80% of capacity. There have been times when the units on the line have been loaded to about 110% of capacity for the short time it takes to bring in another unit.

During rainstorms, an additonal unit is necessary to take care of the added pumping load.

Load demands vary from 2250 K.W. present normal dry weather full load, down to 1200 K.W. for the normal after midnight load. During rainstorms, the demand has peaked to about 3,000 K.W.

No difficulty was experienced in parallel operation nor in the maintenance of the 60 cycle designed frequency even when as many as five generating units were on the bus simultaneously during test runs.

Meaning of Proper Maintenance

Successful parallel operation of dual-fuel engines using minimum pilot oil is largely dependent on proper engine maintenance. Sloppy tappet clearances, incorrect fuel proportioning and incorrectly adjusted fuel nozzles will lead to very heavy load exchanges between generators.

One of the problems encountered during substantial dual-fuel operation has been carbonization of the fuel nozzles. This carbonization becomes evident when the resultant poor ignition causes erratic firing in the cylinder affected. It was found that operating the engines as full diesels for about four hours, on a 500 running hour basis, under normal load helps overcome this condition.

Since the plant went into operation and up to December 31, 1955, the engines have been on the line for a combined total of over 91,000 hours. The enforced shutdowns during that period have been negligible.

In February, 1956, the fourth overhaul of the valves was started. All that has been found needed was the refacing and lapping-in of the valves and seats. No replacements of these parts were found necessary as yet.

In the scheduled inspection after 12,000 hours of operation every wear point in the engines was checked. Wear was found to be far less than had been expected.

The piston rings were renewed, in order to forestall possible excessive oil consumption before the next scheduled 12,000 hour inspection. The rings removed were found to be in such good condition that they are being carried in stock as spares. It was necessary to replace only four connecting rod bearings because of babbit separation.

Credit for the trouble-free operation of the engines is due to the operating and engine maintenance forces for their sincere efforts in the strict adherence to their respective maintenance schedules.

Economy of Power from Dual-Fuel Engines and Generators

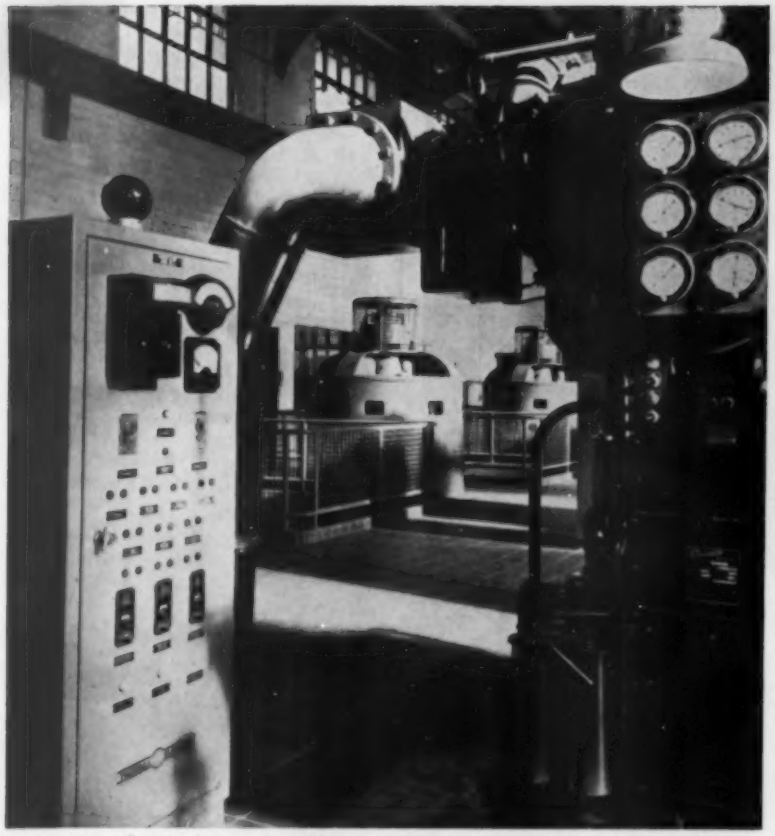
The economy of power generation at the Owls Head Plant, using dual-fuel engines, can be best illustrated by considering the accompanying cost tabulations.

The present personnel could operate and maintain generating equipment capable of producing about 70% more power than the present daily average, of 42,000 KWH. However, in computing the personnel cost, the figure used was 42,000 KWH. On this basis, the personnel cost is $0.0042 per KWH.

The design and construction of the main building, part of which is used to house the generating units, is in keeping with the highly regarded residential section in which the plant is located. $1,064,900 of the total cost of this structure and $815,900 of the cost of the generating units, with their auxiliaries and the gas holder, have been charged to power generation.

With amortization of the structure on a 40 year basis and that of the equipment on a 25 year basis, using the straight line depreciation method at 3% interest, the amount chargeable to power generation for interest and amortization is about $88,400 per year or about $7400 per month.

In the design of the Owls Head



AUTOMATIC control cubicle (one to each engine) has signal lights for all normal, and alarm signals for all abnormal conditions.

plant it was anticipated that the ultimate average daily sewage flow, which would be gradually increasing during the useful life of the power generating equipment, will approximate twice the present flow. On this basis, the average monthly power consumption during this period will be—

$$\frac{(42{,}000 \text{ KWH/day} + (42{,}000 \times 2)) \, 30}{2}$$

= 1,890,000 KWH/month

$7400/1,890,000 KWH = $0.0039KWH

Maintaining that part of structure housing the engines is $5,000 per annum or $417 per month: and, $417/1,890,000 = $0.0002 KWH.

The cost of replacement parts used and engine repairs performed by contractors, for the period from January 1, 1953 to December 31, 1955 amounted to $12,650. This amount is chargeable to actual power generated.

$12,650/36 Mo. = $350 per month.

$350/1,260,000 = $0.0003 per K.W.H.

During this period lubricating oil cost was $0.0001 per K.W.H. on the basis of 42 cts. per gallon.

Recapitulation

Total cost of power generation per K.W.H. at the Owls Head plant during the three years of operation reported is as follows:

Operating personnel	$0.0042
Structure and equipment	$0.0039
Maintenance of building	$0.0002
Engine parts and repair	$0.0003
Diesel oil	$0.0009
Lubricating oil	$0.0001
Total per K.W.H.	$0.00096

Comparing Cost of Purchased Power

Were utility power used at this plant, the cost to the City would be $0.0137 per K.W.H. This is based on the following prevailing utility rates and on an average monthly consumption of 1,260,000 KWH and a 2700 KW demand.

Utility Rates Per Month

$0.016 per K.W.H. for the first 100,000 K.W.H.	$ 1,600.00
$0.009 per K.W.H. all over first 100,000 K.W.H.	$10,440.00
$1.76 per K.W. demand for the first 500 K.W.	880.00
$1.40 per K.W. demand for all over first 500 K.W.	3,080.00
$0.001 per K.W.H. coal charge	1,260.00
	$17,260.00

Average monthly charges:

$17,260/1,260,000—$0.0137 per K.W.H.

The difference between the cost of power, if purchased, over that of gas generated power at this plant is $0.0041 per K.W.H. This difference represents an average saving of $61,667 annually, representing an overall saving of $185,000 for the three years, during which by-product power has been developed with dual-fuel engines. This amount will increase, of course, with the increase of sewage flow.

It must be noted also that during the heating season, there is a saving of about $36.00 per day due to the utilization of heat extracted from the engine jacket water and from the exhaust water heat boilers. These two heat sources provide about 60% of the winter requirements for building and digester heating.

The cost data shows that the selection by the department engineers of dual-fuel generating units for power production, as against purchasing utility power at the Owls Head plant, has been well justified. It is also apparent that in installations similar to Owls Head plant, where digester gas can be produced in sufficient quantities, the use of dual-fuel generating units is both feasible and economical.

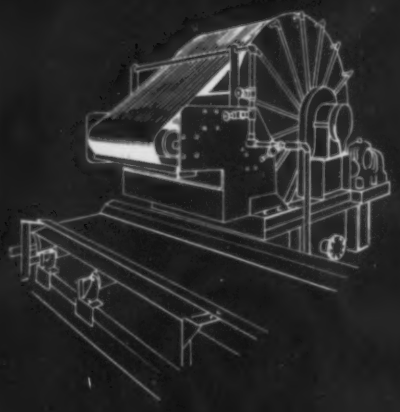
PERSONNEL

(Total cost per KWH = $0.0042)

	A	B	C	D	E
Watch Engineer	$22.57	3	7	60%	$284.38
Watch Oiler	$17.72	3	7	100%	$372.12
Utility Man	$13.50	3	7	50%	$141.75
Machinist	$20.35	1	5	100%	$101.75
Machinist Helper	$17.35	1	5	100%	$ 86.75
					$986.75
Supervision, Clerical				15%	$148.00
City's Share of Pension				10%	$113.47
Total per Week					$1248.22

A—Salary rate per diem
B—Number of watches per day
C—Number of days worked per week
D—Percent chargeable to power generation

The COILFILTER Story

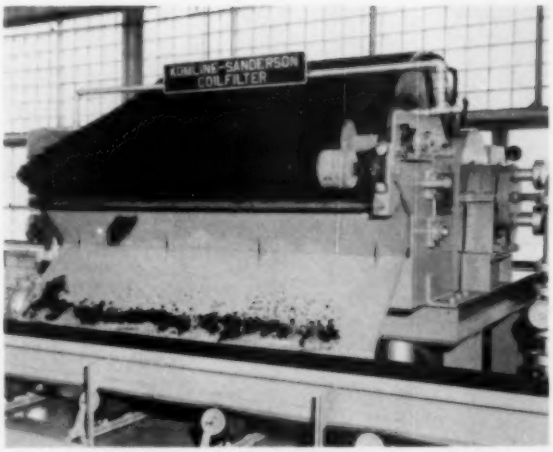


KOMLINE-SANDERSON ENGINEERING CORPORATION

COILFILTER

PROVED SLUDGE DEWATERING WITH PERMANENT FILTER MEDIA

In the few years since the first working installation, at Liberty, New York, in 1949, the Komline-Sanderson Coilfilter has become the first choice of engineers and municipal officials for the efficient and economical dewatering of raw or digested sewage sludge. This pre-eminent position in the vacuum filter field was earned—and is maintained—on the basis of day-by-day performance.



WHAT IS THE COILFILTER?

The Coilfilter is the creation of the imagination and inventiveness of T. R. Komline who, with W. H. Sanderson, formed Komline-Sanderson in 1946 and set up shop in a small plant in Glen Rock, New Jersey. In 1950 the move was made to the present site in Peapack, New Jersey.

The Coilfilter was designed to answer the need for an efficient filter unit:

a. Without the old-fashioned cloth filter media that required a complete shutdown for cleaning or replacement at frequent intervals.
b. Constructed entirely of wear and rot-resistant materials.
c. Requiring a minimum of labor and maintenance.
d. Providing a constant, uniform product.
e. Making sludge beds unnecessary.
f. Permitting a more compact, more economical plant.

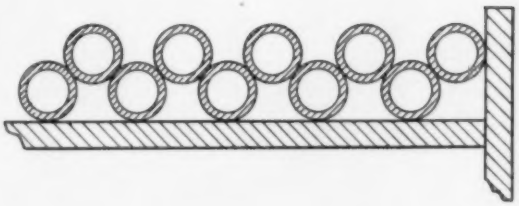
The Coilfilter fulfills all these requirements, and many more. It is the modern sludge vacuum filter designed for the modern, growing community, where adaptability, dependability and economy are fundamental requisites.

- **NON CLOGGING**
- **CONSTANT OUTPUT**
- **PERMANENT FILTER MEDIA**
- **ECONOMICAL OPERATION**

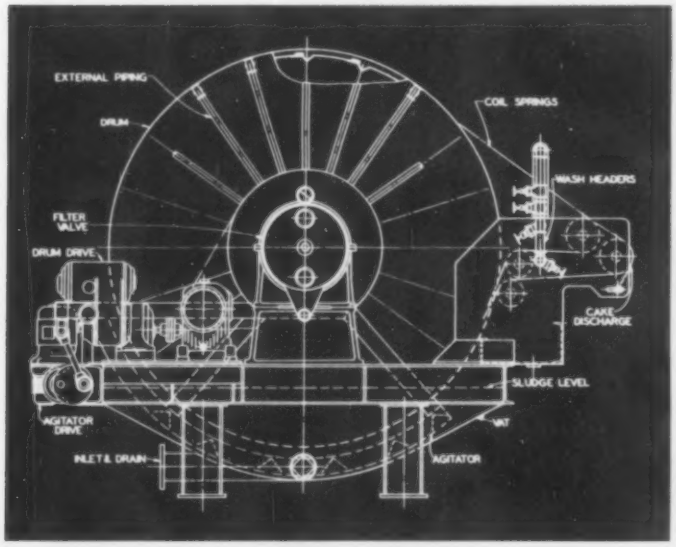
THE COILFILTER PRINCIPLE...

The basic Coilfilter principle is incorporated in its effective and exclusive permanent-type filter media and the performance derived from its continuous flexing and automatic cleaning action. This filter media consists of two layers of stainless steel, helically coiled springs 0.410" in diameter, placed in corduroy fashion around the filter drum. (See line drawing at right)

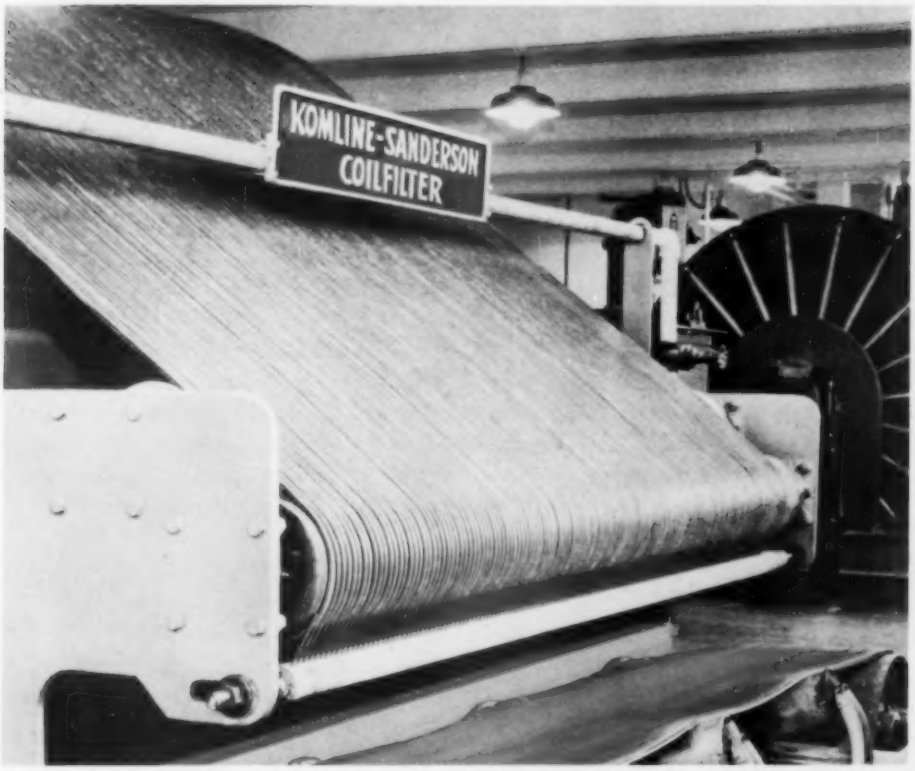
During the cake formation and cake drying cycles, these springs are wrapped around the slowly revolving drum, the lower layer being in grooves in the division strips of the drum so that the springs are taken off a portion of the drum and separated from each other by two discharge rolls in such a manner that the cake is lifted off the lower layer and is discharged from the upper layer of springs by means of a tine bar. Both layers are then washed by means of special flat spray nozzles and reapplied to the drum by grooved aligning coils.



As the coil springs travel over the discharge rolls they bend, or flex, first in one and then in a second direction, while being washed. This guarantees a constantly clean filter media as it begins the dewatering cycle, one of the reasons for the Coilfilter's remarkable success.



Coilfilter Elevation



COILFILTER ECONOMY

The self-cleaning, permanent-type filter media of the Coilfilter (described in detail on page 3) produces a greater volume of filter cake, with greater uniformity, than any other type of sludge dewatering equipment. This makes possible a smaller plant, at less cost.

Since the permanent type filter media does not clog or blind, chemical conditioning of the sludge is far less critical than with other types of filters. Lower-than-optimum chemical dosages are very often permissible, resulting in considerable savings.

The Coilfilter requires no stand-by filter unit, since the equipment does not require shut-down for cover changing or replacement. Nor is the full time of an operator required while the unit is filtering. Coilfilter's low maintenance needs, external piping design, with rugged, stainless steel drum deck and springs, completes a picture of true economy.

THE COILFILTER MAKES DRYING BEDS OBSOLETE

The Coilfilter has had a profound effect upon the basic design of sewage treatment plants. There is an increasing trend toward mechanical sludge dewatering on Coilfilters, and away from the use of sludge drying beds. Beds require lots of room, are expensive to build and to maintain. The cost of removing sludge from beds is surprisingly high and it is difficult to get men to do this unpleasant job.

When additional beds are required due to growing population, land may not be available. This results in overloading of digesters, which in turn affects operation of the entire plant.

Coilfilter dewatering is the answer. Less plant area is required, and, most important, dewatering can be put on a regular schedule, independent of weather conditions.

The high, uniform rate of filter cake production from both raw and digested sludges—the proved operating economies and compact plant permitted by the Coilfilter—the adaptability to meet changing conditions: These are some of the reasons why drying beds have been made obsolete by the Coilfilter.

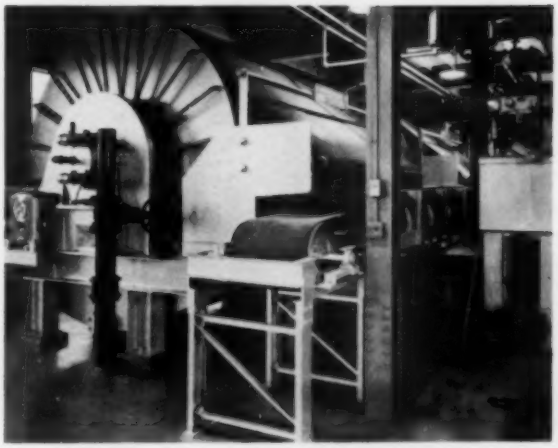
COILFILTER replaces sludge drying beds at Mt. Penn, Pennsylvania.

WHY COILFILTER LEADS THE FIELD...

As the only *performance-proved* sludge vacuum filter with permanent-type filter media and as the leading modern sludge filter, by far, in the municipal sewage treatment field, the Coilfilter offers design, construction and operating advantages available in no other filter system. Some of these advantages are:

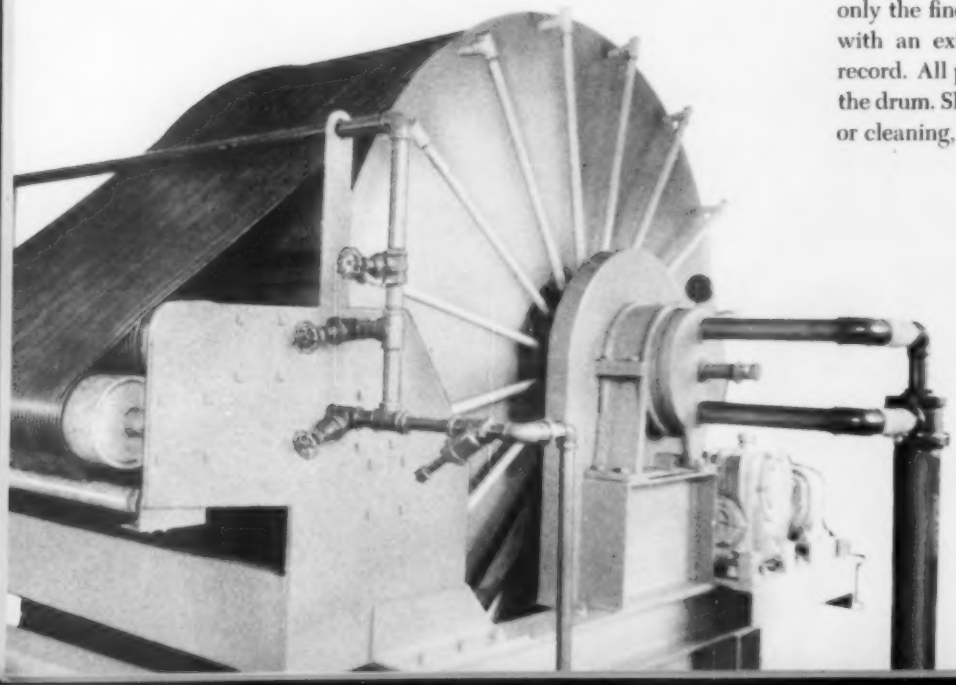
PERMANENT, NON-CLOGGING FILTER MEDIA

Stainless-steel, helically coiled spring filter media cannot clog or blind and has an indefinite life. Automatically washed after each dewatering cycle, the filter media results in greater production of cake, with no time lost in media cleaning or replacement.



RUGGED CONSTRUCTION

Since the Coilfilter is manufactured entirely of wear and rot resistant materials, it is immune to ordinary deterioration and will last indefinitely. Komline-Sanderson uses only the finest materials. Result—a product with an extremely low parts replacement record. All piping is straight and external to the drum. Should it ever require replacement or cleaning, the job is quick and easy.



...PERFORMANCE-PROVED FEATURES

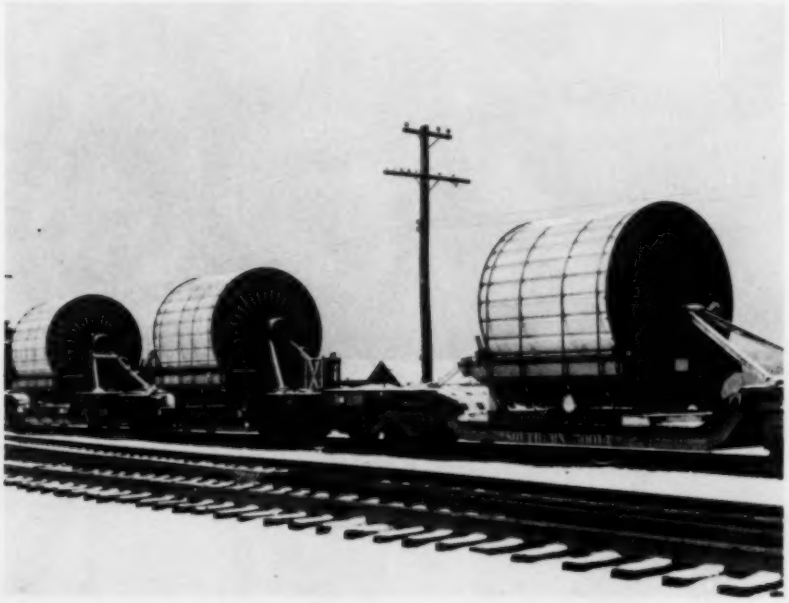
CONSTANT OUTPUT

No sludge dewatering system can match Coilfilter's performance-proved volume of filter cake production. Non-clogging, self-cleaning filter media maintain constant, uniform efficiency, making costly controls unnecessary.

OPERATING AND CAPITAL COST ECONOMY

The Coilfilter is the most economical of all sludge vacuum filters:

1. No standby filter necessary, reducing size of installation and number of units required.
2. Lower chemical conditioning requirements—less cost.
3. Sludge drying beds unnecessary. More compact plant.
4. Little operating labor required. No filter cloths to change.
5. Extremely low maintenance requirements. Easy cleaning. Very little parts replacement.



Three large COILFILTER UNITS leaving the plant at Peapack en route to installation at Louisville, Kentucky.

Komline-Sanderson Service

Komline-Sanderson service begins at the very start of a project. After our representative has discussed the design conditions and requirements of a future plant with the Consulting Engineer, and transmits this information to the home office, our experienced staff goes over the conditions and makes its recommendations.

The Engineer then receives a complete discussion of the bases used in arriving at our recommendations, together with sample specifications, typical layouts which may be appropriate, detailed equipment drawings and a price and weight analysis. Our Engineering Department is always available for whatever help and guidance we can offer.

After an order is received for Coilfilter and auxiliary equipment, we furnish promptly detailed layout and equipment drawing as well as certified specification sheets.

Komline-Sanderson always furnishes the services of a competent and experienced service man for a period of two weeks to supervise the initial operation and to provide proper instruction to the operators in the operation of the complete filter installation. Our service men also check on proper installation. After beginning operation the Service Department is always available for advice or a personal call when needed.

Installation

We have developed and are continuing to develop and improve much of the auxiliary equipment used in Coilfilter installations. In order to assume complete responsibility for the proper performance of the complete sludge dewatering installation, it is our policy to furnish all necessary equipment. **1.** Coilfilter **2.** Vacuum and Filtrate Equipment **3.** Conditioning Tank **4.** Wet Sludge Handling Equipment **5.** Conditioning Chemical Feeders, Pumps and Tanks **6.** Cake Handling Equipment

Our Engineering staff is ready to submit preliminary performance data involving the use of Coilfilters in your plant, upon receipt of the following information: **1.** Type of treatment plant. **2.** Whether sludge is to be digested. **3.** Design data, flow and suspended solids or population equivalent. **4.** Number of hours of filter operation per week desired.

users approve COILFILTER

Here is what a few users have to say about Coilfilters:

LIBERTY, NEW YORK

HARRY EICHENAUER, Plant Superintendent: *". . . In regard to coil spring filter as compared to cloth filter, I would much prefer the coil spring. I used a cloth filter here for about ten years before replacing it with the coil spring. . . . If your chemical dosage should be a little off one doesn't have to worry about blinding, as with a cloth filter. After having operated the two kinds, I much prefer the coil spring . . ."*

ST. CHARLES, ILLINOIS

WM. B. CLARKE, Superintendent of Public Works: *". . . And, with the Coilfilter, chemicals now required for sludge conditioning are less than 50% of the quantities formerly used; the chemical treatment is no longer critical; the coil spring filter media never clogs or blinds; manual cleaning and replacement of the filter media has been eliminated; and operating headaches have disappeared. . . ."*

CONSHOHOCKEN, PENNSYLVANIA

CLARENCE H. COOPER, Superintendent: *". . . This unit replaces two old style cloth type filters whose operation and maintenance costs were entirely unsatisfactory. We feel the Coilfilter embraces truly sound design and exceptional performance, a combination that reflects in a savings of chemical usage and maintenance costs."*

BUCKLIN PT., RHODE ISLAND

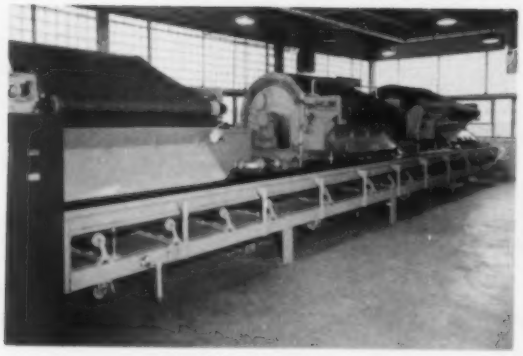
C. V. (BUCK) HICKEY, Plant Superintendent: *"We have been very pleased with our Coilfilters from the beginning, due to their outstanding performance, dependability and low operating cost. In addition, the ease of maintenance, partly due to the accessibility of all points requiring lubrication and adjustment, combined with the excellent general layout of this plant, make this a truly modern installation."*

COILFILTER STANDARD SIZES

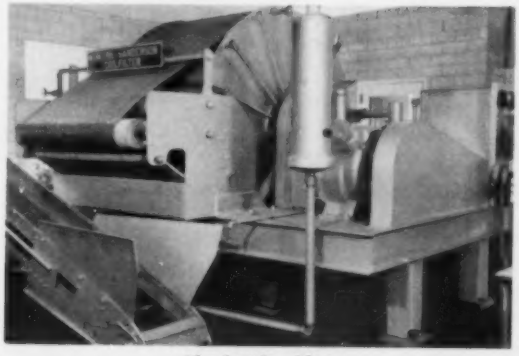
SIZE	AREA SQ. FT.	SIZE	AREA SQ. FT.
*6' dia. x 2'8" face	50	10' dia. x 8' face	250
*7' dia. x 4' face	85	10' dia. x 10' face	300
*8' dia. x 4' face	100	10' dia. x 12' face	350
8' dia. x 5' face	125	11'6" dia. x 10' face	330
8' dia. x 6' face	150	11'6" dia. x 12' face	430
8' dia. x 8' face	200	11'6" dia. x 14' face	500
10' dia. x 4'4" face	200	11'6" dia. x 16' face	575

*Package Unit

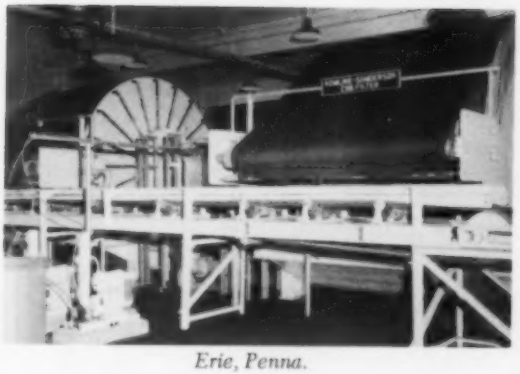
SOME **COILFILTER** INSTALLATIONS . . . .



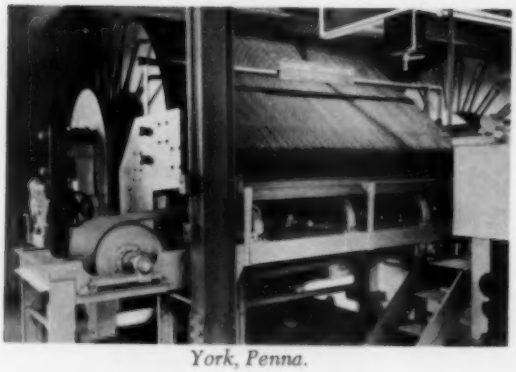
Bucklin Pt., R. I.



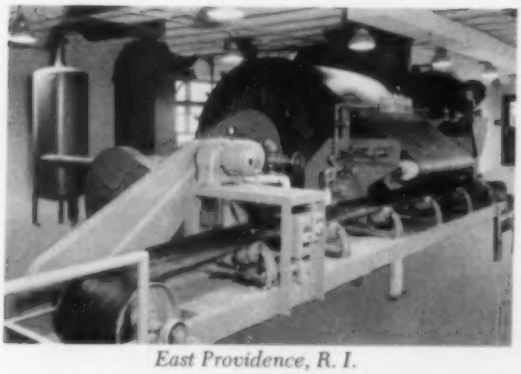
Shadyside, Ohio



Erie, Penna.



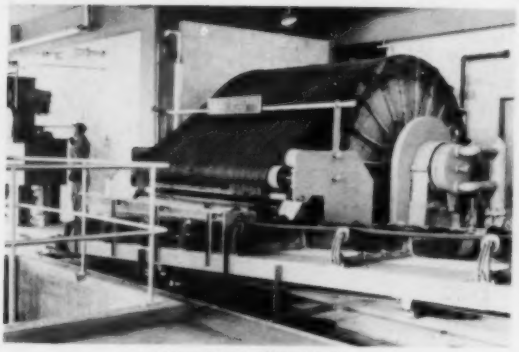
York, Penna.



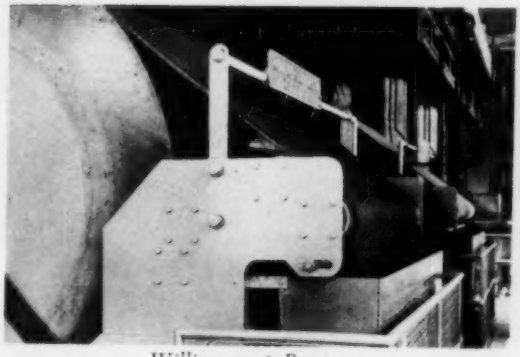
East Providence, R. I.

Perryville, Mo.

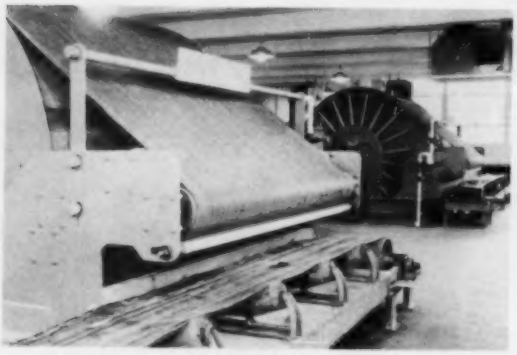
. . . . . IN THE **MUNICIPAL** FIELD



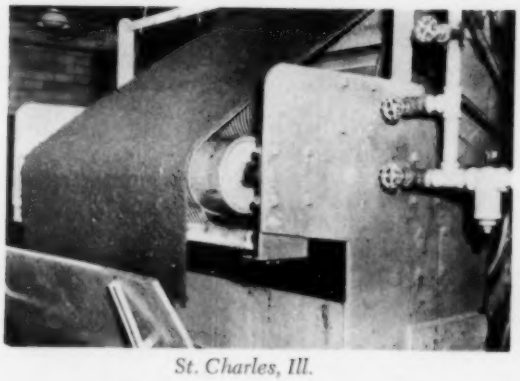
New Rochelle, N. Y.



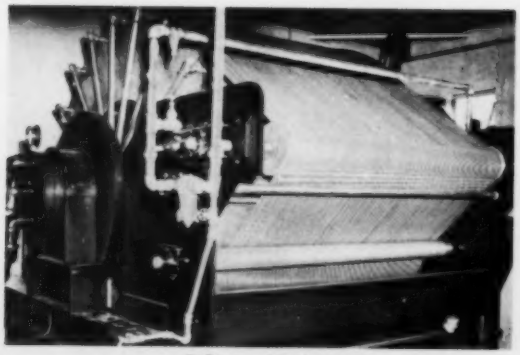
Williamsport, Penna.



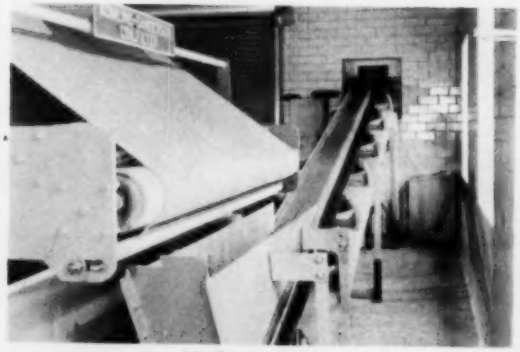
Darby Creek, Penna.



St. Charles, Ill.

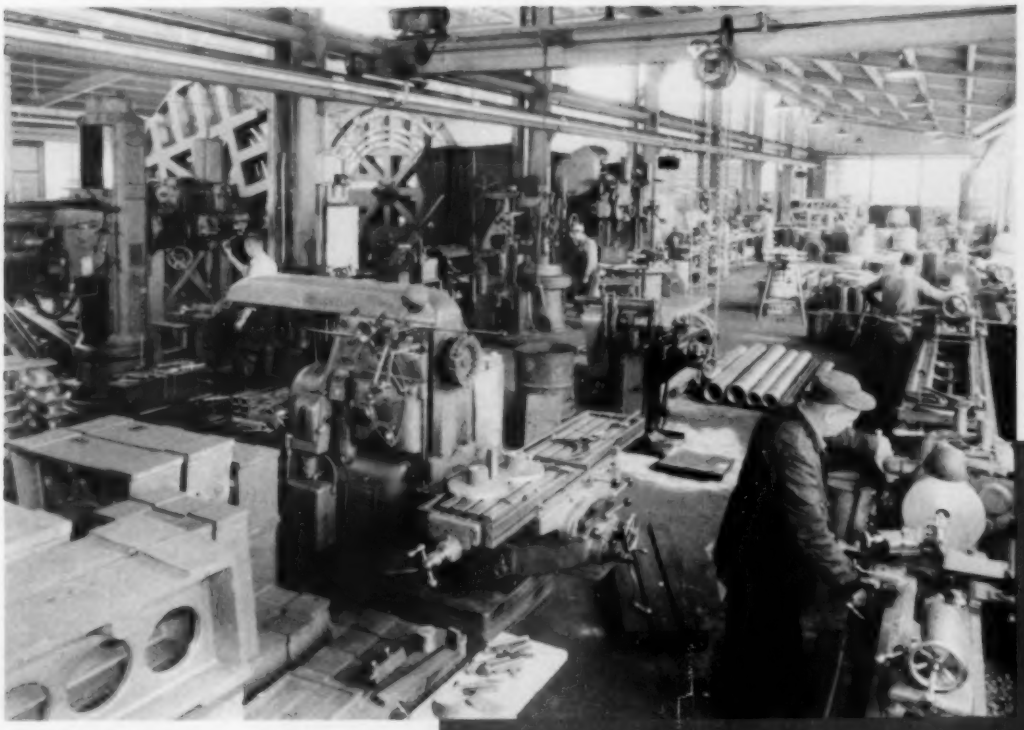


Liberty, N. Y.



Hatboro, Penna.

ever-increasing facilities



Above: a section of our large and completely equipped machine shop.

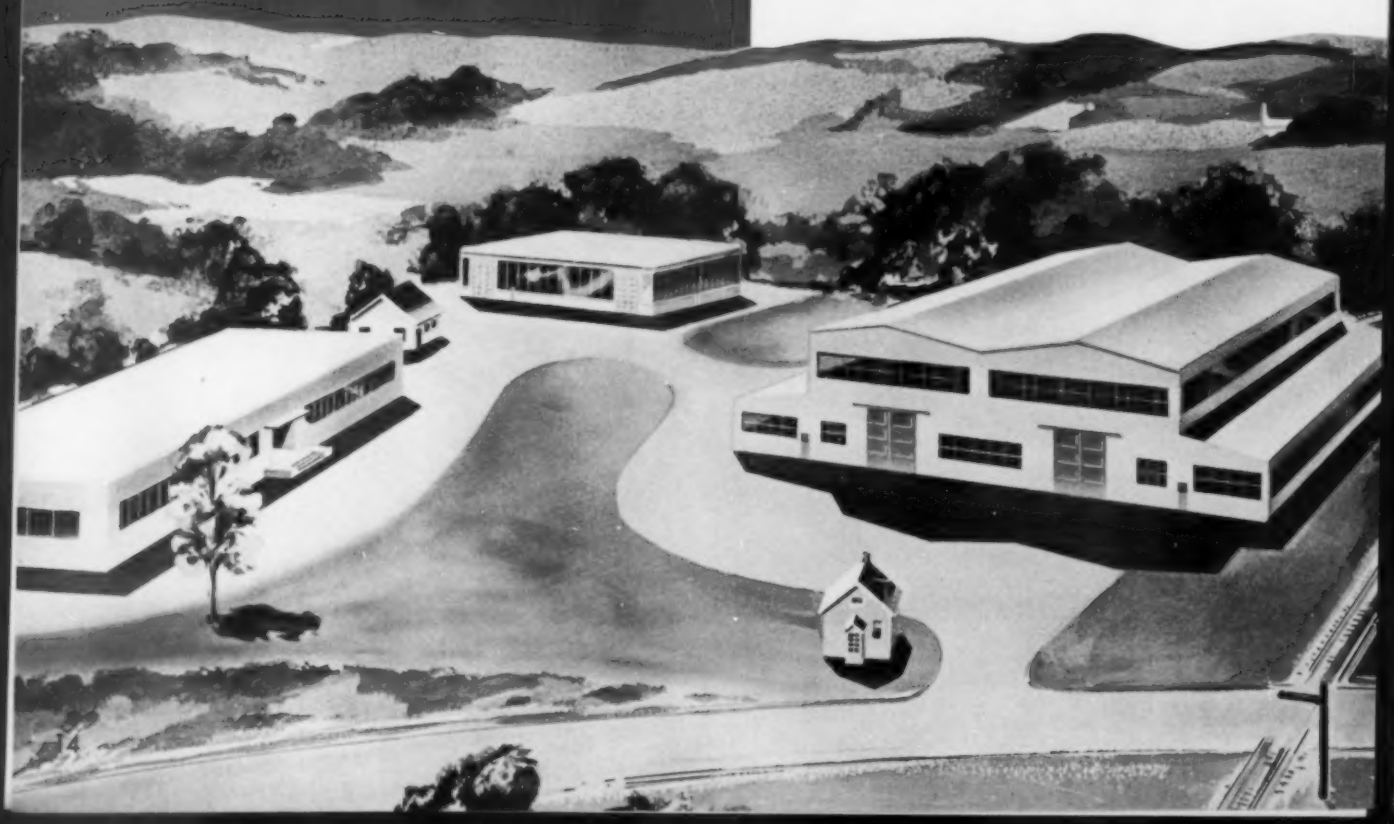
At right: Part of the Komline-Sanderson Engineering Department.

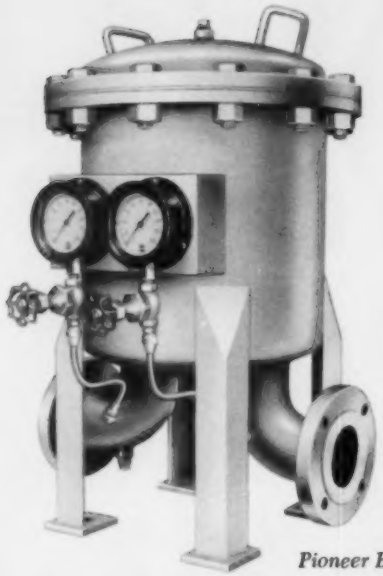
Above: Large adjustable welding jig in our machine shop, used in fabricating COILFILTER drums.

Below: Outside view of machine shop.

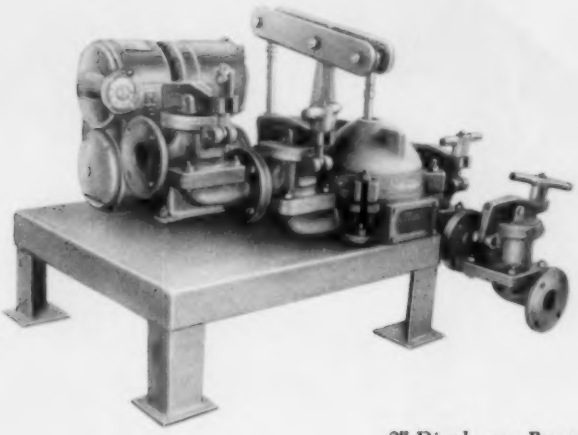
Above: Research and development activities are centered in this modern, well-equipped laboratory.

Below: The Komline-Sanderson plant as it is to be in the near future, when present construction is completed. The three large structures are, left to right, the Administration Building, Warehouse, Manufacturing.



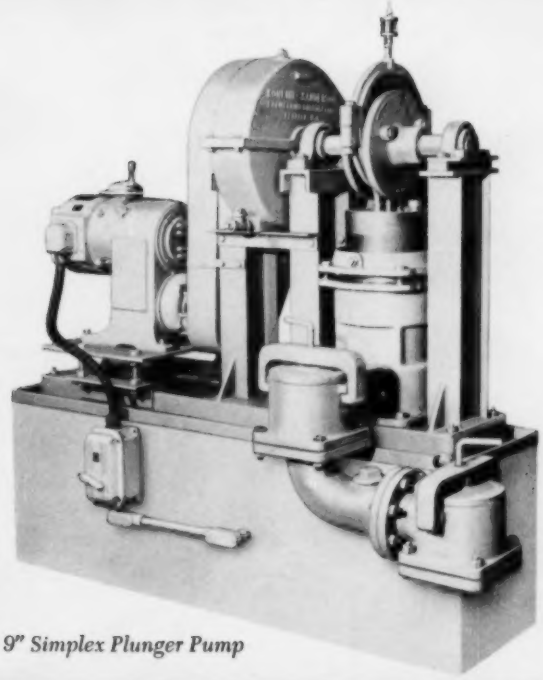


Pioneer Bulk Filter

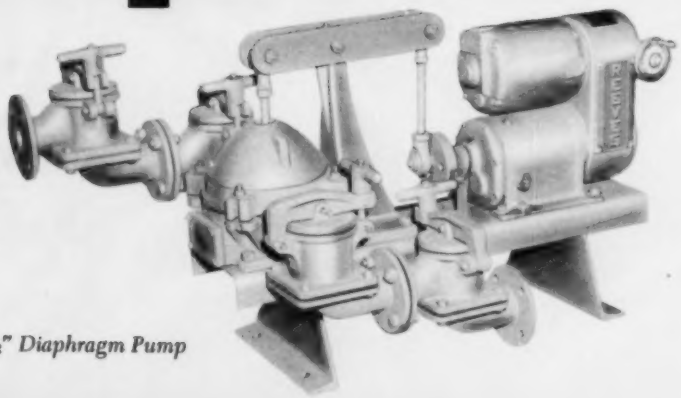


2" Diaphragm Pump

OTHER KOMLINE-SANDERSON PRODUCTS



9" Simplex Plunger Pump



2½" Diaphragm Pump

DEDICATED TO THE CONSERVATION OF AMERICA'S RESOURCES

KOMLINE-SANDERSON ENGINEERING CORPORATION

PEAPACK, NEW JERSEY

Bulletin No. 106 5-57

Printed in U.S.A.

Vacuum Filtration of Raw Sludge

Practices and experiences at Minneapolis-St. Paul

by KERWIN L. MICK and SCOTT E. LINSLEY

Respectively Chief Engineer and Superintendent and Assistant Engineer of the Minneapolis-St. Paul Sanitary District

ONE OF THE MOST expensive operations in the treatment process for sewage plants located in densely populated metropolitan areas is that of sludge disposal. Of the plants requiring sludge dewatering, the vacuum filtration operation is costly, demands a great deal of close control, and therefore is worthy of considerable attention.

A glance at Table 1 will give an insight into the relative magnitude and importance of expenditures for vacuum filtration compared to other departments at the Minneapolis-Saint Paul sewage treatment works.

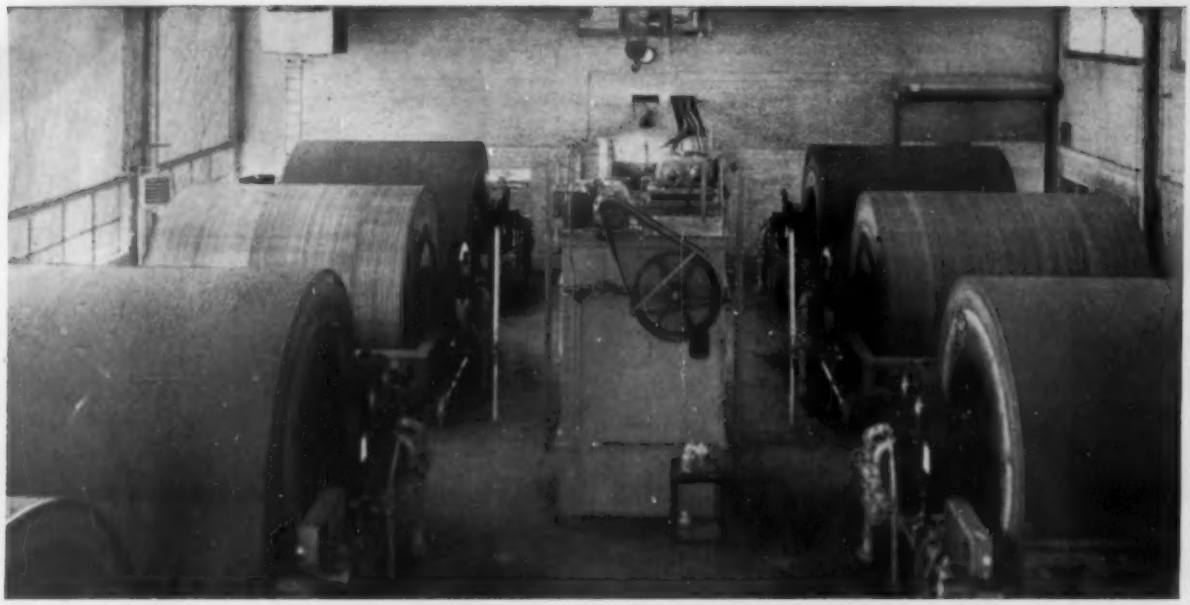
Operating Problems

In addition to economic factors, there are also many other operating problems of which system stability, uniformity of sludge cake moisture, maintenance, and heat balance are of primary importance. The system of sludge disposal employed at Minneapolis-Saint Paul is a continuous 24-hour a day process employing incineration; therefore, cake moisture control assumes added importance due to the evaporative load besides the combustive load applied to the system.

Control of moisture of the sludge cake in the vacuum filtration process is effected primarily by adjusting the following factors:[1]

1. Filter drum speed (drying time, cake thickness, and agitation).
2. Washing rates (frequency, duration, and fluids applied).
3. Chemicals used for sludge conditioning.
4. Sludge levels in the filter basins and mechanical arrangement of piping, valves, bridges, and drainage structures (baffling for controlling run-back, blow-back, etc.).
5. Filter media (porosity and rate of blinding).

MINNEAPOLIS—ST. PAUL Sewage Treatment Works on the Mississippi River



VACCUM filter room with eight filters

The Minneapolis-Saint Paul Sanitary District sewage treatment plant vacuum filters raw sludge. The sludge is pumped from each of six settling tanks once every eight hours to a pair of concentration tanks where it is held between 24 and 48 hours and approximately ¼ of its volume pumped back to the settling tanks as supernatant liquor. After concentrating the sludge, it is fed by gravity to a conditioning tank and then to a battery of eight 11½ ft diameter x 14 ft long Oliver vacuum filters.

For ten years prior to 1955, the solids in the sludge cake averaged 31.6 per cent and a considerable excess of heat existed in the cake over the requirements necessary to evaporate all of the water in the cake, effect complete combustion, and raise the temperature of all gases generated high enough to eliminate offensive odors.

The dry solids in the sludge cake for 1955 averaged 27.3 per cent, the decrease being due principally[1] to changing the filter media from a napped 8-oz. Canton flannel to a 32 x 32 mesh Saran cloth screen woven from a 10 mil monofilament saran plastic yarn and[2] to a drastic reduction in the amount or at times complete elimination of chemicals used for sludge conditioning. This change in solids content resulted in a reduction of the amount of excess heat available for evaporation and draft purposes. Even with this change, oil is still rarely needed as an aid to combustion and normally is only necessary when shutting down an incinerator or starting one up (a two to three day process).

Improvements in Conditioning

For many years, considerable attention has been devoted to the mechanics of sludge conditioning, distribution, mixing, agitation, proportioning, hydrogen-ion concentration, and the like, with steady improvement in efficiency. Notable changes effecting substantial improvements in sludge conditioning were the following:

1. The addition of a lime slurry riffle board or distributing board and screen in the conditioning tank.
2. The provision of low pressure air agitation at the bottom of the tank thru a series of small holes connected in groups to separate air headers.
3. Internal baffling to improve mixing and avoid short-circuiting or segregation.
4. Piping, valve, vent, and conditioning tank revisions providing for feeding eight vacuum filters from one, two, or either of two bucket elevators and one conditioning tank.
5. The addition of equipment to utilize the carbide lime slurry waste product from Twin Cities acetylene generators.

In the original design of the vacuum filters, it was necessary to shut a filter down before it could be washed. Washing was accomplished by a set of sprays attached to a piping header on the backside of the filter drum (the side away from the discharge side). In 1955 the Sanitary District staff developed a new method of washing wherein the sprays were moved to the front side of the filter immediately under the take-off plate. A wash-water trough was installed immediately under the spray assembly and it is now possible to wash all filters while they are operating, resulting in greater efficiency both as

TABLE I

Account No.	Department	% of Total Cost *
1	Administration	10.1
2	Supervision and Engineering	10.9
3	Laboratory	5.7
4 & 5	Grit and Screenings Removal and Disposal	8.5
9 & 10	Sedimentation and Scum Disposal	10.7
13	Vacuum Filtration of Sludge	25.9
14	Sludge Cake Incineration and Disposal of Ash	14.6
—	All Others	13.6
	Total	100.0

*Based upon MSSD Annual Reports.

TABLE 2

Some Biennial Comparative Costs of Vacuum Filtration Years 1954 and 1955

Vacuum Filtration Costs, Year 1954

Iron Coagulant	$ 37,098.61
Lime	17,899.94
100 Filter cloths incl. wire @ $31.89+$19.28	5,117.00
8 Filter cloths incl. wire @ $87.91+$19.28	857.52
Power and Light	18,179.63
Acid to cloths, 339 carboys @ $5.56	1,884.84
Maintenance	29,775.84
*Attendance (Salaries and Wages	74,337.28
*Attendance (Miscellaneous	954.31
Total	$186,104.97

Total tons dry sewage solids filtered — 40,909
Total cost per dry ton = $4.55

Unit Costs Per Dry Ton

		% of Total
Iron coagulant	$0.91	20 } 30
Lime	0.44	10 }
Filter Cloths + Wire + (L&M)	0.15	3
Elec. Power & Light	0.44	10
Acid to Cloths	0.05	1
Maintenance	0.72	16
Attendance (Sal. & Wages	1.82	40
Attendance (Misc.	0.02	—
	$4.55	100%

Vacuum Filtration Costs, Year 1955

Iron Coagulant	$ 14,759.76
Lime	14,034.60
6 Saran cloths, incl. wire @ $90.25 + $20.32	663.42
Power and Light	18,107.33
Acid to cloths, 97 carboys @ $5.23	507.31
Acid to pipes, woodwork, etc. 131 carboys @ $5.23	685.13
Maintenance	41,066.81**
*Attendance (Salaries and Wages	79,181.53
*Attendance (Miscellaneous	2,261.09
Total	$171,266.98

Total tons dry sewage solids filtered — 44,126
Total cost per dry ton = $3.87

Unit Costs Per Dry Ton

		% of Total
Iron Coagulant	$0.33	9 } 17
Lime	0.32	8 }
Filter Cloths + Wire + (L&M)	0.02	1
Elec. Power & Light	0.41	10
Acid to cloths	0.01 }	1
Acid to Pipes	0.01 }	
Maintenance	0.93	24
Attendance Sal. & Wages	1.79	46
Attendance (Misc.	0.05	1
	$3.87	100%

*Note: Cost figures are based on MSSD Annual Financial Reports.
**This figure includes 100% internal piping and replacement in six filters, which would normally depreciate about 1/17 per year

to equipment utilization as well as economy of treatment.

Filter Media

Several varieties of filter media were tested ranging through the various weights of napped and non-napped Canton flannels to poplin and cheesecloth, with always a return to the 8-oz. napped Canton flannel. In late 1954, Walter M. Kunsch, Supt., Sewage Treatment, Waterbury, Conn. courteously made available technical data on his experimentation and research utilizing polyethylene and Saran filter medias. The data[2] indicated the probable feasibility and practicability of using the new Saran filter media at Minneapolis-Saint Paul. The results, to say the least, were spectacular.

Table 2 shows some comparative costs before and after the change to the new filter media. In 1954, 8-oz. Canton flannel was used until November 4 when conversion was made to Saran. That date marked the beginning of the learning period when certain old operating practices had to be discarded and new ones established. In 1955, the new filter media was used the entire year.

There are several basic operating changes that have made these results possible. For example:

1. The life of an 8-oz. Canton flannel filter cloth averaged 465 hours for the past five years before it was blinded so badly that it became useless. Vacuum filter speeds ranged from 7 to 14 revolutions per hour for these cloths. The average life of the Saran cloths or screens used in 1955 before discard was 5,743 hours. Further, this is not a very representative figure since some of these cloths still had adequate porosity but failed mechanically. At this writing, two cloths have been in service in excess of 10,000 hours and are still being used.

TABLE 3

Vacuum Filtration Chemical Cost Summary—1955

	Unit Cost Per Ton of Solids Filtered				Total For Month and Year		
	Dry Basis			Volatile Basis	Filtered Solids	Chemical Cost	
1955	Iron Coag.	Lime	Total	Total	Dry Tons	Actual	*Deviation From Mean
January	$0.09	$0.25	$0.34	$0.45	3,550	$ 1,210	$ —3,050
February	0.01	0.02	0.03	0.04	3,219	110	—4,070
March	0.06	0.05	0.11	0.16	3,590	400	—3,860
April	0.19	0.19	0.38	0.55	1,845	710	—2,130
May	0.16	0.28	0.44	0.60	4,021	1,790	—3,970
June	0.37	0.34	0.71	1.04	4,662	3,320	—2,710
July	0.97	0.50	1.47	2.26	3,919	5,760	—1,180
August	0.77	0.59	1.36	1.95	3,868	5,280	— 420
September	1.14	0.64	1.78	2.43	3,612	6,430	+ 480
October	0.43	0.44	0.87	1.15	3,991	3,460	—2,100
November	0.11	0.33	0.44	0.57	3,787	1,650	—2,820
December	0.04	0.20	0.24	0.31	4,062	950	—4,290
TOTAL					44,126	$31,070	$—30,120
Inventory & Pricing Correction						2,270	2,270
YEARLY AV.	$0.33	$0.32	$0.65	$0.90		$28,800	$—32,390

*Deviation from expected costs based upon a 5-year average % Fe and % CaO on a volatile solids basis for corresponding months (1950-1954)—See Table IV.

2. Another change is the drastic reduction in the amount of iron coagulant required as well as the substantial reduction in the lime requirement, over $32,000 less than anticipated. Note Tables 3 and 4. The primary consideration in these two factors is the operating ability to remove the cake from the filter drums, and secondarily, to control the moisture to the point necessary for economic incineration conditions.

3. For more than ten months it was also possible to reduce the filter washing rate from once every hour to once every two hours, thereby effecting additional economies.

The rather poor savings indicated for August and the higher cost for September is partially due to leaky internal vacuum filter piping on six of the old drums (following 17 years of operation). After replacement, vacuums rose to normal values and only one vacuum pump was required

Insofar as over-all plant operation is concerned, no deleterious effects have been observed. Efficiency of removal has been maintained. The suspended solids in the sludge filtrate averaged 110 ppm for the five-year period 1949-53, and 2,000 ppm for 1955; however, the total solids in the sludge filtrate averaged 3,500 ppm and 4,850 ppm for the same respective periods. Further, settleable solids are removed and sent back thru the sludge disposal process a second time and if any are left, they continue to recycle.

MULTIPLE hearth Nichols incinerator

Future Investigations

As to the future, there are several avenues of investigation which seem worthy of the effort:

a. Since filter drum speed is a major factor in sludge cake moisture control, studies will be made toward determining the optimum economical drum size and operating speed ranges suitable for use with other existing equipment, plant space, and capacity available. In addition, these factors will be determined for a new or original installation as well.

b. Vacuum filter design and construction as to run-back, blow-back, drainage, and washing will be investigated since the units no longer function wholly as originally intended and certain economic improvements reducing maintenance and attendance as well as increasing capacity can probably be effected.

c. There are at least two radically different vacuum filters now being used in the sludge vacuum filtration field, namely, the Komline-Sanderson coilspring filter and the Eimco Roto-Belt filter employing a woven metal filter media. So far, there are insufficient technical data available as to sludge cake moisture content to be expected in a continuous 24-hour day, year-round operation, and the economic merits of the investments involved to provide a sludge cake of the required moisture content. These two types of units should also provide an interesting and practical avenue of investigation and approach to the sludge dewatering problem.

TABLE 4

Chemicals Used (Volatile Solids Basis)

Period	1955		5-Year Average 1950-1954	
Month	% Fe	% CaO	% Fe	% CaO
January	0.16	2.73	1.49	3.63
February	0.01	0.28	1.46	3.49
March	0.11	0.58	1.62	3.19
April	0.37	1.66	1.50	3.20
May	0.27	2.18	1.54	3.90
June	0.67	3.99	1.63	4.65
July	1.88	5.96	2.51	5.66
August	1.43	6.20	1.79	5.29
September	1.81	6.02	1.77	5.02
October	0.71	4.40	1.55	4.60
November	0.18	3.17	1.26	4.11
December	0.06	1.58	1.26	3.94
Avg. for Year	0.65	3.33	1.58	4.29

References:

(1) Note the research on this subject by A. J. Beck, et al, page 689, Vol. 27, No. 6, June 1955, Sewage and Industrial Wastes.

(2) Private letters from Walter M. Kunsch, Superintetndent, Waterbury, Conn. Sewage Treatment Plant, July and August, 1954.

Sludge Dryers and Incinerators

by FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

Multiple Hearth Incinerators

A CONSIDERABLE number of multiple hearth sludge incinerators have been installed in the United States, the larger installations being at Detroit, Minneapolis-St. Paul, Cleveland, and Columbus. Representative smaller units include those at New Britain and New Haven, Conn.; Wyandotte, Mich.; Ashland, Piqua, and Barberton, Ohio; and Elmira, N. Y. All of these units were manufactured by the Nichols Engineering & Research Corp.

The Martin multi-zone furnace, presently manufactured by Morse Boulger Destructor Co., has been installed for sludge incineration at Raritan and Rutherford, N. J.; Lansing, Mich., and Wisconsin Rapids, Wis. At present only the Lansing unit is in operation and that for sludge drying. Similar units have been installed for incineration of screenings at Niagara Falls, N. Y.; and Milwaukee, Wis.

Design Features

The multiple hearth furnace consists of a cylindrical shell mounted on columns supporting hearths one above the other, the shell lined with a wall of insulation and firebrick.[1] A vertical air-cooled central shaft revolves and turns horizontal arms above each hearth. Teeth attached to these arms continually stoke or rabble the sludge so that it moves progressively downward through the furnace. When designed as an incinerator, hot gases produced by the burning of volatile matter in the sludge, or from supplementary fuel such as oil or gas, pass upwards through the furnace in counter current to the sludge.

Special provisions are advisable if the multiple hearth unit is to provide for both incineration and drying. In addition to the method above described while operating as an incinerator, provision should be made for burning oil or gas over the upper hearths and drawing the hot gases down through the furnace parallel with the travel of the sludge.

The Nichols Multiple Hearth Unit at Dayton, Ohio, has been operated in this manner as a drier since 1939. Digested sludge partially dewatered on sludge-drying beds is further dried to below 8 per cent moisture for sale as fertilizer. Sludge gas burns on the upper hearths and supplies the heat for drying.

At the Toronto Ashbridge's Bay plant two multiple hearth units designed to either incinerate or dry sludge cake, and with a unit capacity to evaporate 12,000 lb. of moisture per hour, have been contracted for. Provision will be made in connection with these units to mix a portion of the dried sludge removed from the bottom hearth with the filter cake before the latter is admitted to the top hearth.

In the following text the writer has summarized operating experiences with multiple hearth units at a number of sewage treatment plants, based upon personal observations, published reports, and comments by the plant operator. The observations presented should not be construed as criticism of designers, manufacturers, or operators. It is the intent to record difficulties which have been experienced, measures taken to improve conditions, and to record operating results so that others facing similar problems may profit thereby.

Detroit

The largest installation of multiple hearth sludge incinerators is at the Detroit sewage treatment plant. There are four units each 22 ft. 9 in. outside diameter with 12 hearths as initially installed and a rated capacity of 330 tons of sludge cake per day. The initial plant included preheaters designed to use the hot gases leaving the incinerators to preheat the air used for combustion. In actual operation, the heat value of the volatiles in the raw sludge under normal conditions of operation have been more than sufficient to support combustion. The operation of the preheaters was not necessary and in fact not desirable.

Operating difficulties with the incinerators at this plant disclosed the necessity for a number of changes in methods, equipment, and appurtenances in order to obtain best results.

In the operation of the Detroit incinerators, it has been found that excessive temperatures caused damage to the equipment and low temperatures caused excessive smoke in which case the burning of large quantities of fuel oil would be required to correct the situation. An important operating feature has been the control of the feed to prevent sudden changes, particularly in the amount of grit and screenings. The problem created by the screenings disposal was in large measure solved by grinding and returning them to the sewage flow. Until recently, it was not practical to dispose of all the grit removed at the plant by incineration. However, changes now being made which include grit storage and feed by means of screw conveyors at a uniform rate from the storage hopper to the conveyor belts discharging to the incinerators should make it practical to incinerate all of the grit with a minimum of operational difficulty.

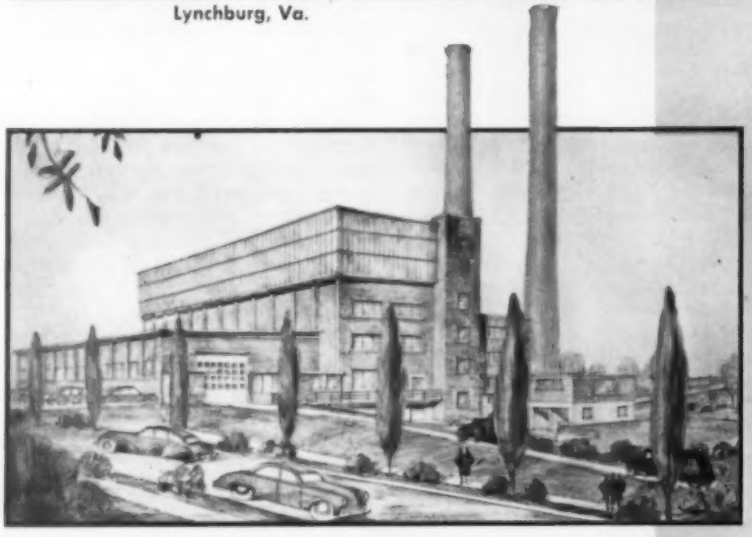
The initial reciprocating plate feeder on several of the individual incinerator units has been replaced with a variable speed ribbon conveyor and storage bin. This change is reported to have resulted in the elimination of smoke leaks, better and more uniform distribution, and less violent temperature changes.

Some rabble arms are of 12 percent chromium and 12 percent nickel, others are of Nercaloy. The rabble arms of 25 percent chromium and 12 percent nickel must be insulated in the combustion zone in order that they may have reasonable life. Replacement of rabble arms has been greatly reduced since temperatures have been controlled at under 1,600 deg. F. for most of the time. Temperatures are controlled by allowing cool air to enter the furnaces through

1 Recent refractory hearths have been cast in place in certain locations within the incinerator units. There are indications that this type of hearth is more satisfactory for some hearths than those made of individual firebrick blocks.

Lynchburg, Va.

Drying Sludge for Fertilizer — The new sewage treatment plant at Lynchburg, Virginia, is designed for a population equivalent of 70,000. It will have a design flow of 11,000,000 gallons per day and will produce primary digested sludge. A C-E Raymond Flash Drying System, complete with storage bin and bagging equipment, will dry this sludge for use as a fertilizer. The flash drying equipment will evaporate 2,750 pounds of water per hour while producing 1,225 pounds of dry solids.
Wiley & Wilson, Engineers.



Louisville, Ky.

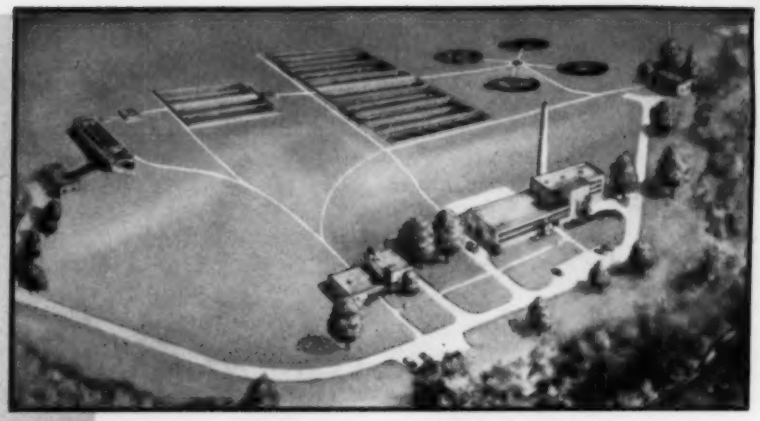
Drying and/or Incinerating Sludge with Refuse — The two C-E Raymond Flash Drying Systems to be installed in Louisville's new refuse disposal plant provide an economical and flexible sludge disposal facility. Sludge filter cake will be trucked from the sewage treatment plant to the refuse disposal plant. Utilizing the refuse incinerator's waste heat, the C-E Flash Drying Units dry the entire sludge output. It can then be sold as fertilizer or used on municipal golf courses, parks and lawns. Unused sludge can be incinerated with the City's refuse. The plant serves a population equivalent of about 500,000.
Metcalf & Eddy, Engineers.

THEY CHOSE C-E

Pittsburgh, Pa.

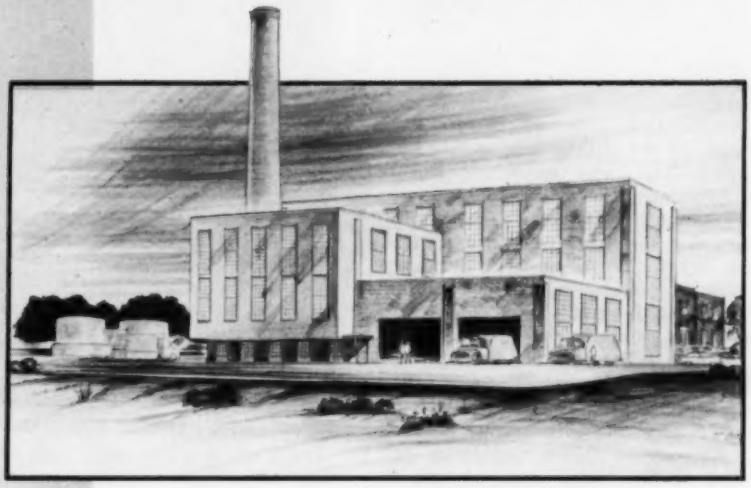
Sewage Sludge Incineration — This seventeen million dollar plant will serve seventy communities in the Pittsburgh area, having a population equivalent of 1,500,000. It will include four C-E Raymond Flash Drying and Incineration Systems capable of handling over 300 tons of concentrated sludge per day. They are designed to burn 55 tons of dry solids while evaporating more than 250 tons of water. Each unit will be equipped with a Deodorizing System to free all foul gases of objectionable odor. In addition, each unit will incorporate equipment for the control of fly ash.
Metcalf & Eddy, Engineers.

Drying and/or Incinerating Sludge — This plant, designed to serve an equivalent population of 136,000 in the Warren area, will produce both activated and raw primary sludges. Three C-E Raymond Flash Drying Systems will dry and/or incinerate its entire output. Because of the heavy concentration of diversified industry in the Warren area, it is planned to use only one of the three C-E Raymond units to dry sludge for use as a soil conditioner. The remaining two units will be used for incineration, but can be quickly and easily converted to fertilizer production. ***Johnson & Anderson, Engineers.***



Warren, Mich.

Disposal of All Municipal Wastes — This new plant will dispose of all municipal refuse from the cities of Neenah and Menasha, Wisconsin. Garbage, rubbish and refuse, and sewage sludge will be burned in two C-E Traveling Grate Refuse Incinerators. Heat from the incinerators will be used in a C-E Raymond Flash Drying System to dry the entire output of sludge from the sewage treatment plant. Once dry, it can be used for fertilizer, if desired, or returned to either or both of the incinerators and burned. ***McMahon Engineering Co., Engineers.***



Neenah-Menasha, Wisc.

RAYMOND IN 1956

The C-E Raymond Flash Drying and Incineration System for sewage sludge disposal is the most versatile and flexible system available. As evidenced by these brief descriptions of some 1956 contracts, the C-E Raymond Flash Drying System can be used to dry sludge for use as a soil conditioner, to incinerate it to a sterile ash, or both. It can be combined with existing refuse incinerators or installed integral with the C-E Traveling Grate Refuse Incinerator to take advantage of available waste heat resulting from the incineration of garbage and refuse. It can be equipped with its own heat source, burning either dry sludge or purchased fuel.

If you are considering new sewage disposal facilities — alone or in combination with refuse disposal, see C-E. We will be happy to discuss your needs with you and with your consultants.

COMBUSTION ENGINEERING

B-994

RAYMOND DIVISION, 1315 North Branch Street, Chicago 22, Illinois
Eastern Office: 200 Madison Avenue, New York 16, N. Y.
Western Office: 510 West Sixth Street, Los Angeles 14, Cal.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

the hearth doors and by regulation of butterfly dampers in the enlarged section of the ducts ahead of the stacks.

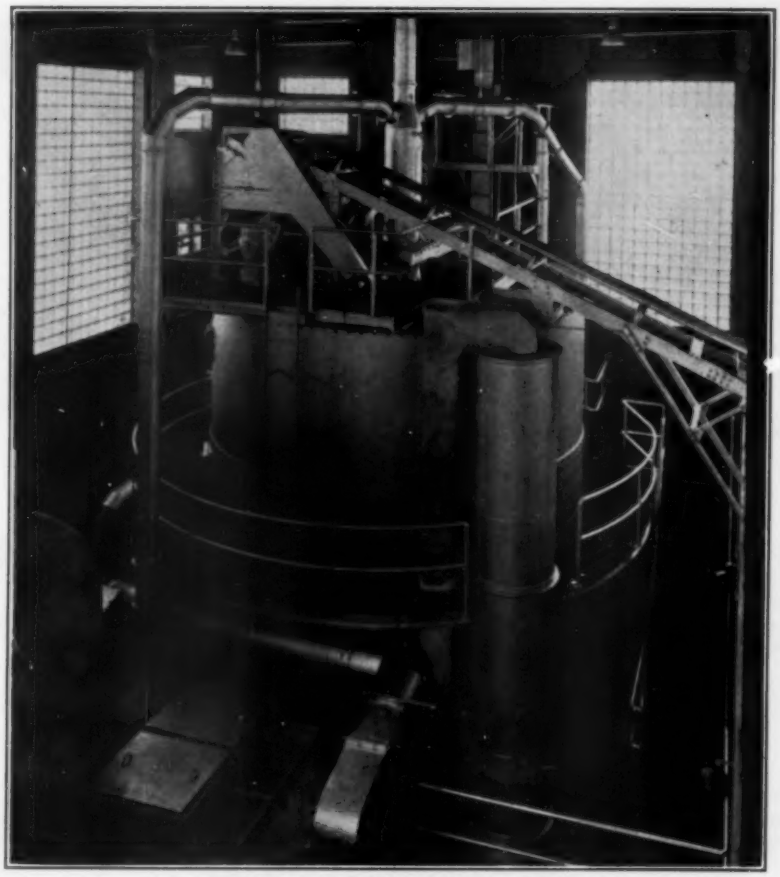
Weightmeter counters have been installed on the control board and also in the filter room to permit closer observation and control of the feed rates.

The linings in the steel stacks through which the vapors from the incinerators are discharged, as initially constructed, were not suitable for the temperatures encountered. Recently corrosion, reportedly caused by acids present in the flu gases, has been a serious problem at the inner faces of incinerator shells, breechings and stacks.

Improvements to incinerator No. 4 have increased its rated capacity to 14 or 14½ tons of sludge cake per hour. The normal working capacity for average monthly production is 12 to 13 tons per hour. This remodeled unit has 11 hearths and enlarged drop holes in the drying and combustion zones. The most important feature improvement to this unit was the additional flue capacity. A large number of lance holes were provided on out hearths to facilitate cleaning and to provide an abundance of fresh air. The latter is reported to be of importance to minimize slagging.

During 1949 the incinerators burned all of the 194,797 tons of filter cake produced at the plant, all of the 1,132 tons of scum removed from sedimentation tanks, and 99.97 percent of the 15,127 tons of grit removed from the grit chambers.

How unit unloadings on multiple hearth incinerators may be best expressed is still a question. The interior diameter, number of hearths, net hearth area, volume for combustion, moisture evaporated, solids destroyed by incineration and ash handled, are important factors. Assuming adequate volume is provided for combustion per unit of hearth area, a unit of loading in terms of pounds of moisture evaporated and solids burned per square foot of net effective hearth area may have significance for purposes of making comparisons of performance between units at various plants. A test load on Detroit incinerator No. 4 resulted in the incineration of 14.31 tons of sludge cake per hour. This cake contained 36.41 percent solids and 52.08 percent volatiles dry basis. The moisture evaporated was about 9.1 tons per hour and the solids incinerated were about 2.7 tons per hour. The net hearth area of this incinerator is 2,500 sq. ft. and the load during this test per square foot of net area per hour was equivalent to 7.28 lb. of water evaporated and 2.16 lb. of solids incinerated, making a total of 9.44 lb. of water and volatiles. Including ash, the rate was 10.5 lb. per sq. ft. per hr.



Lansing, Mich.—Martin Multiple Hearth Incinerator

The ash sluicing pumps have been taken out of a pit and installed at floor level to facilitate their servicing and maintenance.

As first constructed, the Detroit incinerator building was poorly ventilated. In the warmer months, the temperature in the upper operating gallery and under the roof was said to be over 130°F. and there was considerable odor of scorched sludge. Subsequently, four ventilating exhaust fans each of 40,000 cfm. capacity were installed on the roof of the incinerator building to exhaust smoke and gases and to improve conditions within the building.

Minneapolis-St. Paul

There are three multiple hearth incinerators at this plant, each 22 ft. 3 in. outside diameter and with eight hearths. Each unit as provided had a rated capacity of 60 tons of dry solids per 24 hr., based on 65 percent moisture in the filter cake and 60 percent combustible matter in the dry solids. A fourth similar unit is under construction. Grit and scum are not burned in the incinerators.

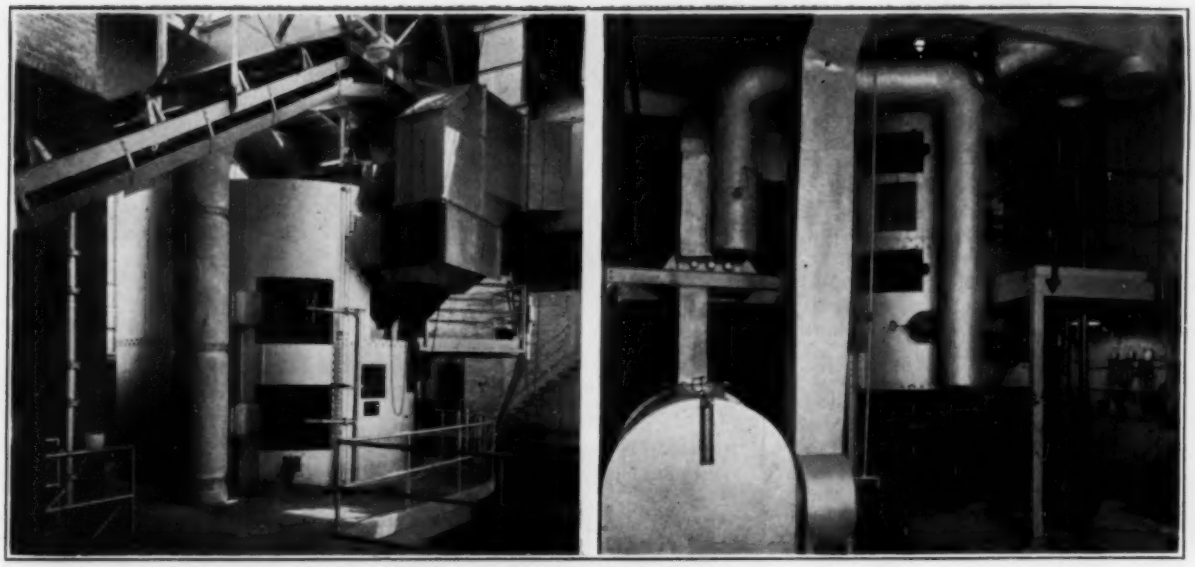
The design assumed that supplementary fuel would be required for incineration of the sludge and that temperatures could be controlled by regulation of the feed of the fuel. However, it was found under practically all conditions of operation an excess of heat existed and no supplementary fuel was required.

Instead of an anticipated maximum temperature of 1,600 deg. F. actual temperatures exceeded 2,200 deg. F.

The preheaters were removed from service with resultant reduction in power and maintenance costs.

It was found that if the feed rate was kept below 1.4 tons of combustibles per incinerator per hour excessive temperatures were practically eliminated. A chart was prepared showing safe rate of feed of filter cake to an incinerator unit for various percentages of solids and combustibles. The operators have found this chart very useful as a guide to operation.

The net hearth area is 2,084 sq. ft. per unit. The nominal capacity of each incinerator unit is equivalent to about



Two examples of small Nichols Multiple Hearth Incinerators Wyandotte, Mich. (on left) and Middletown, Conn. (on right)

5.4 lb. per hour of moisture evaporated and solids consumed per square foot of net hearth area. On occasion, the units have been reported to satisfactorily handle an overload of approximately 33 percent. On the annual average the units operate at between 85 and 95 percent of the time.

Based on present rated capacity of 1.4 tons of combustibles per incinerator hour, the three incinerators for the past 2 years have averaged approximately 72 percent of capacity. At numerous times during the year individual furnaces may be operated at near capacity for several days at a time.

Maximum temperatures of incinerators are kept below 1,600 deg. F. by operation of an induced-draft fan with variable-speed drive. The fan follows a duct in which water is added as necessary to keep the gas temperature at the fan below 700 deg. F. and protect the fan from damage by overheating. The speed of the fan is controlled from the main operation panel where the hearth temperatures are also recorded.

Ventilation in the incinerator building has been somewhat of a problem. Fixed glass blocks have been replaced by ventilating sash across one end of the building to supplement the three large ventilators placed in the roof. A wall fan has been added to cool a "dead" area in one corner of the incinerator. A similar fan is to be installed over the fourth incinerator now being built.

Cleveland-Southerly Plant

There are four multiple-hearth furnaces at this plant, each unit 18 ft. 9 in. outside diameter with eight hearths. The specified capacity per unit was 100 tons of digested sludge filter cake at 75 percent moisture content per 24-hr. day. In 1940, it was reported that these units could be operated at the average rate of 60 tons per incinerator day. In 1941, the capacity was reported to have been reduced to 50 tons per incinerator day. The inability to obtain design capacity was said to be primarily due to rapid accumulations of fly ash in the preheater passages. It was impossible to clean these passages with the preheaters in operation. On this account, the incinerators suffered from lack of adequate draft and a reduction in capacity.

In 1942, three of the eight preheaters were eliminated, the other five cleaned and repaired, the combustion air ducts were enlarged, a bypass provided around the preheater units, gas boosters were added, and the number of gas burners was increased. Subsequently, the preheaters have been used infrequently. As a result of these changes, the unit incinerator capacity was increased to 80 tons of cake per day in 1943. The rate of operation with cake containing 31.9 percent solids of which 38 percent were volatiles was equivalent to 3.43 lb. of moisture evaporated, 0.60 lb. of volatiles consumed, and 4.03 lb. of moisture and volatiles per square foot net hearth area per hour. The average rate of operation in 1945 was 81.6 tons of cake per unit, the cake containing 28.4 percent solids of which 44.3 percent were volatile. The unit load in pounds of moisture evaporated and pounds of volatiles consumed was substantially the same as for the 1943 rated capacity as given above.

The multiple-hearth units at this plant were designed and initially operated on a somewhat different principle than those handling raw sludge at Detroit and Minneapolis-St. Paul. The top four hearths were drying hearths and are separate from the lower hearths. The hot gases from the combustion hearth beneath the drying hearth did not pass up through the upper hearth, instead they passed through the preheaters and thence up the stack. The gases from the drying hearth at a temperature of 500 deg. F. were passed through the preheaters where it was intended that they be raised to a deodorizing temperature of 1,200 deg. F. and then cooled down to about 500 deg. F. before being discharged to the stack.*

The preheaters are of the steel plate envelope type. As originally installed they were not suitable for the service. Dust and fly ash accumulated in the passages, greatly reducing their capacity and seriously limiting the output of the incinerators. The preheater units could not be cleaned without shutting down the incinerators and the cleaning operations were difficult to perform. In the operating reports, it is stated that the steel envelopes warped even though temperatures were kept within permissible limits. A portion of the preheaters were reported to have burned out during 1941.

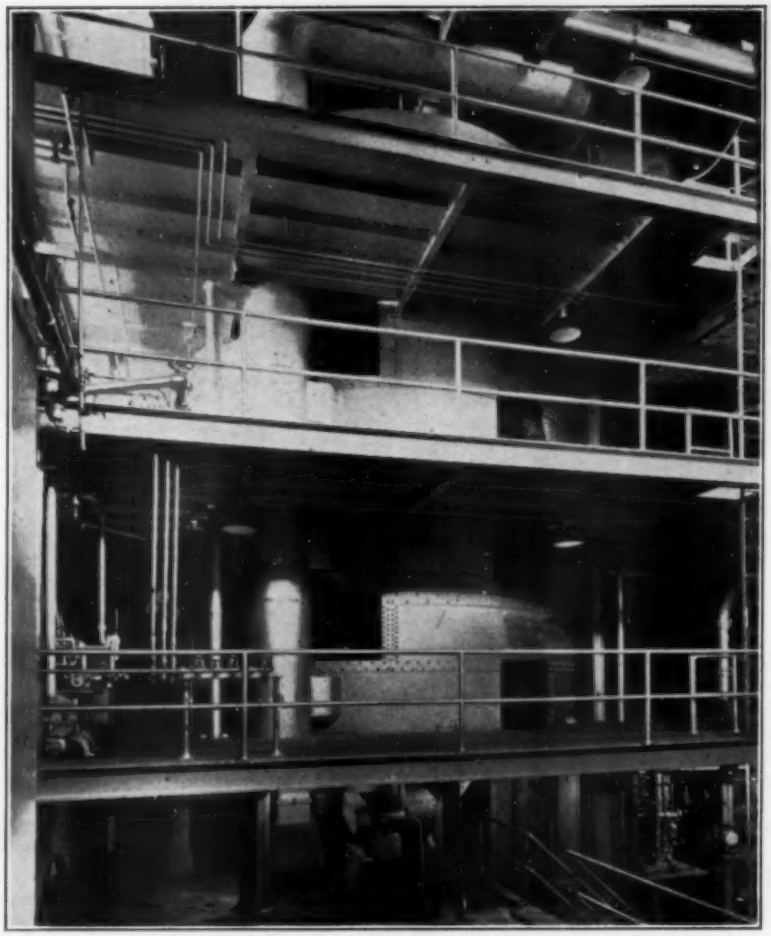
*In 1942, after the incinerators were revamped, the method of burning sludge was on the same principle as at Detroit and Minneapolis-St. Paul.

Occasional operating difficulties reported include the slowdown or partial interruptions by brick falling out of the hearth, by clinkering of the ash, and by burning out of the bag filters on the ash line.

In 1944 it was reported that considerable trouble was experienced with the warping of the rabble arms and teeth especially on hearths 5 and 6. The pyrocast arms which were used during that period were insulated with Kastset using nichrome wire as reinforcement to prevent warping. One ring of the refractory was removed from hearth 5. Eventually rabble arms on the lower or combustion hearths containing 25 percent chrome and 12 percent nickel were found to be satisfactory.

Theoretically all the vapors and gases discharged from the stack have passed through deodorizing temperatures. The stack extends only a few feet above the roof line and the wind currents from the bluff above the plant drive the vapors down to ground level. Observers have reported that at times a decided odor of scorched sludge has been detected in the vapors from the stack.

Ventilation in the incinerator building during the summer months has been reported as unsatisfactory. During this period, there is a tendency for the operators to spend as much time as possible out of doors.



Minneapolis-St. Paul Sanitary District Incinerator

Columbus, Ohio

The multiple hearth incinerator at Columbus has an outside diameter of 16 ft. 9 in. and has six hearths. It was designed to incinerate 80 tons per day of digested sludge containing 75 percent moisture and 12½ percent combustible matter wet basis. It is reported to have a capacity to burn 50 tons per day of digested sludge filter cake at 75 percent moisture and 50 percent volatiles dry basis. The net hearth area is 845 sq .ft. The reported unit capacity is equivalent to 3.70 lb. of moisture evaporated, 0.56 lb. of solids consumed, and 4.26 lb. of moisture and volatiles per square foot of net hearth area per hour. For 1950 the average feed rate was 1.7 tons per hour of cake containing 28.8 percent solids of which 38.4 percent were volatiles. This is equivalent to 2.87 lb. moisture evaporated, 0.43 lb. of solids consumed, and 3.32 lb. of moisture and volatiles per sq. ft. of net hearth area per hour.

Operating reports indicate that it is necessary to shut down this unit for 15 percent of the time in order to make repairs such as renewing rabble teeth and replacement of rabble arms.

An air preheater of the sectional plate type was originally installed with 2,484 sq. ft. of heating surface. All of the equipment within the preheater was removed after the incinerator was placed in operation and the unit lined with firebrick so as to serve as a flue. The preheater became so caked up that it limited the passage of hot gases and greatly restricted the incinerator capacity.

As originally installed, all of the rabble teeth on the arms over the upper hearth were directed so as to move the sludge toward the outer edge. Two rabble teeth on each arm have been reversed so as to hold back some of the sludge cake and increase the drying time. Observations have shown an unusually deep accumulation of sludge cake, well broken up and well mixed as a result of this minor change. Ordinarily the top two hearths in this unit are drying hearths. The third and fourth hearths are combustion hearths and the fifth and sixth are for completion of combustion and cooling off of the ash.

Some of the heat from the exhaust gases is reclaimed under low-pressure steam boilers and used for heating the plant buildings and the sludge digestion tanks.

As in a number of other plants employing sluicing, ash handling has given considerable trouble at the Columbus plant. Lime is used for sludge conditioning and has accumulated as $CaCO_3$ in the ash hopper and in the ash lines to an extent requiring considerable work for removal. Clinkers have accumulated in the ash tanks and have been difficult to remove. This experience points to the desirability of having a quick-opening gate between the lower hearth and the ash hopper so that ash can be stored on the lower hearth while the work of removing clinkers and lime encrustations in the ash tank is carried on. Also clinkers find their way into the slurry pump, causing serious cutting of the impeller and rubber lining.

Difficulties with calcification in the wet ash discharge lines have led at Columbus to serious consideration of discharging the ash in a dry condition. The operators are of the opinion that if wet ash from lime conditioning

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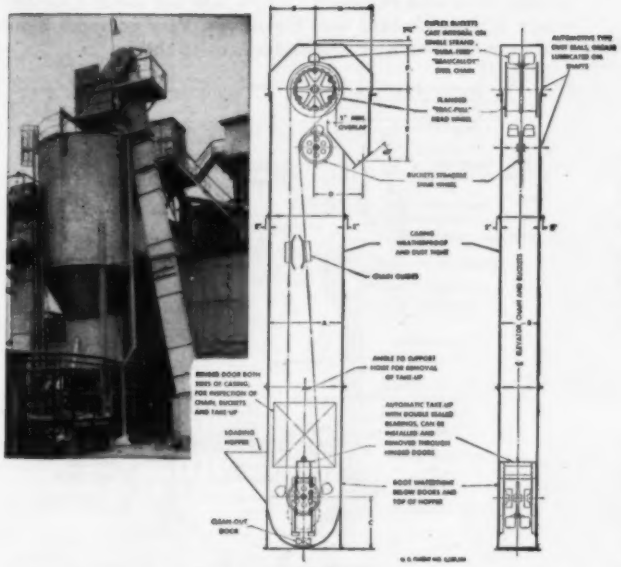

The Beaumont "MULTI-VATOR" incorporates Beaumont bucket elevator equipment made from either of two types of metals—corrosion resistant or abrasion resistant "Beaucalloy." Designed for handling bulk materials of all types including those which are hot, light, fluffy, fine, coarse, abrasive, sticky, or fragile, the "MULTI-VATOR" components include: "Dura-Tred" Chains; "Trac-Pull" Wheels; and "Uni-Cast" Buckets.

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BEAUMONT "DURA-TRED" CHAIN

Cross-section photo of Beaumont No. DT-102B "Dura-Tred" Combination Chain Link. "Dura-Tred" Chain Links are available in both Pintle and Combination types and can be made of malleable iron, Beauco-CR metal, and "Beaucalloy," a heat treated alloy steel. "Dura-Tred" Chains have 450% to 600% more metal in wearing tread which contacts driving wheel than standard chains.

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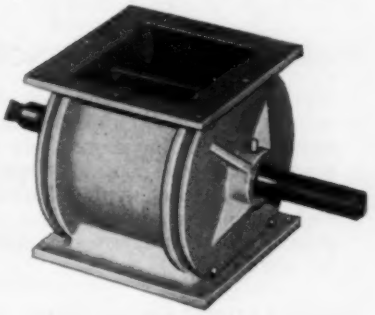
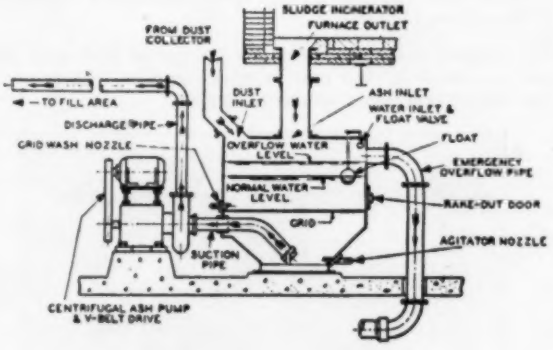
Beaumont Rotary Feeders are ideal for handling fine materials. Easily replacable seals protect bearings and permit feeder to operate under high plus or minus pressures.



Hydraulic, Pneumatic and Mechanical Conveying Equipment for Handling Dried or Incinerated Sludge



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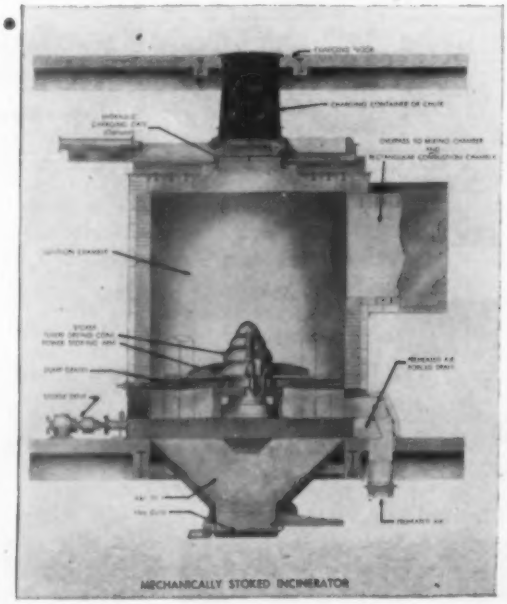
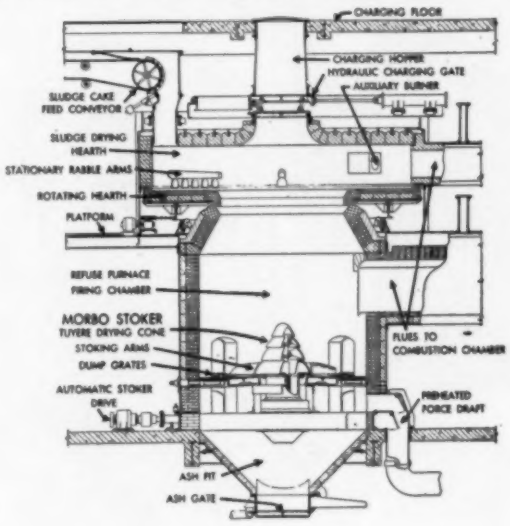
We suggest that you discuss your disposal problems with our engineers as they may involve complex factors where our broad experience would be helpful.



MECHANICALLY STOKED INCINERATOR

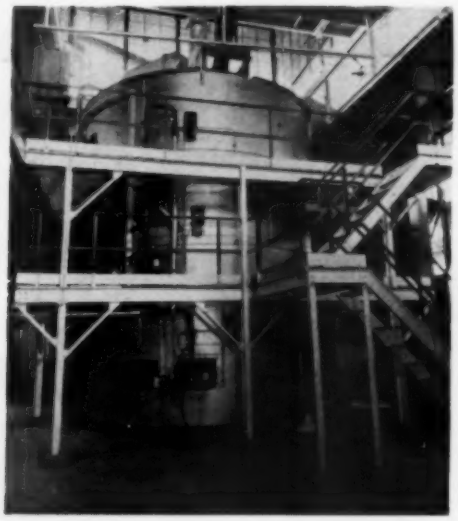
COMBINATION SLUDGE REFUSE INCINERATOR

This type unit is ideal for the smaller community which must dispose of sewage sludge as well as municipal refuse. The sludge is dried on the upper hearth and then rabbled (stationary arms and revolving hearth) into the lower chamber where it is incinerated with the refuse. Very compact plant and economical in both first and operating costs.



MORSE BOULGER MULTIPLE HEARTH FURNACE

Designed to dehydrate or incinerate sewage sludges and many kinds of industrial wastes. Material is rabbled inward and outward as it passes downward from hearth to hearth. Provides maximum pre-drying and incinerating capacity, discharging dry ash from wet sludge feed.



sludge must be pumped, ample provision should be provided for removal of encrustation and the pipeline should be readily accessible for cleaning operations.

The incinerator chimney at Columbus includes a lined steel stack manufactured by Prat-Daniel and designed for a head induced by a cold air fan which acts as an injector. Cold air is forced into the stack near the restricted section so as to create a draft of up to 2 in. in the gases from the incinerator and boilers. The cold air, induced-draft fan has a variable speed drive and the draft can be governed within desirable limits. This arrangement eliminates a hot air induced-draft fan and provides an excellent means for regulation of incinerator operation.

Ashland, Ohio

The results of incineration of liquid sludge at Ashland, Ohio in a multiple-hearth unit have been reported by Laboon.* This unit is 9 ft. 3 in. outside diameter. As initially built it had four hearths. It was found advisable to add two hearths in order to incinerate concentrated liquid sludge in this unit.

The results of 6 days of tests made during September and November, 1947 have been given by Laboon. The unit was operated 140.33 hours, evaporated 146.499 lb. of moisture, consumed 18,473 lb. of volatiles, and passed 6,130 lb. of ash during the period. The unit rate of operation was about 5.39 lb. of moisture evaporated and 0.68 lb. volatiles consumed per square foot net hearth area per hour.

*John F. Laboon, Sewage Works Engineering 1949, p. 64.

Summary

On the basis of operating experience some of the features of design, construction, and operation of multiple-hearth furnaces to be used for driving and incinerating sewage sludge requiring particular care follow:

1. There should be ample capacity to discharge the products of drying and combustion. The drop holes should be of such size as to pass the hot gases upward and the sludge downward without clogging and undue loss of head.

2. Preheaters are not necessary for economical incineration of raw sludge cake.

3. Preheaters if provided should be a type which can be cleaned with facility. An ample bypass should be provided for each preheater unit so that it may be cleaned while the incinerator unit remains in operation. Preheaters of the closely spaced plate type are not satisfactory for this type of service.

4. Adequate means should be provided to permit an even rate of feed to the incinerator unit, particularly of moisture and combustibles. The rate of feeding relatively low volatile grit and relatively high volatile scum should be subject to fairly close control.

5. The rabble arms and teeth in the combustion hearths should be of heat resisting alloys. The central shaft at combustion hearths should be suitably insulated. A liberal allowance should be made as to the extent to which combustion may proceed above and below the theoretical average combustion zone.

6. Consideration should be given to the protection of the incinerator stack against high temperature gases under certain conditions and against the corrosive action of acid and moisture under certain other conditions.

7. The ash system should be designed for ready access. A shutoff gate is desirable between the lower hearth and the ash system so that the latter may be worked on while the incinerator unit remains in operation. Ash slurry discharge lines should be designed so that stoppages may be cleaned or encrustations removed. Duplicate ash discharge lines may be required in order to make shut down unnecessary.

8. Adequate ventilation should be provided in sludge drying and incinerator buildings so that working conditions are not too uncomfortable.

Acknowledgment

Acknowledgement is gratefully made for data supplied by Fred H. Burley, Engineer of Sewage Treatment at Detroit; Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul plant; George E. Flower, Commissioner of Sewage Disposal at Cleveland; James H. Blodgett, Superintendent of Sewage Treatment Works at Columbus; and Robert W. Rowen, Vice President of Nichols Engineering & Research Corporation.

Flash Drying and Incineration

The following article deals only with the product of one manufacturer although the preceding article covered for the most part only the multiple hearth sludge drying and incinerating equipment as manufactured by Nichols Engineering & Research Corp. As heretofore in these articles it is the intent to record operating experiences and measures taken to improve the equipment and its maintenance so that others facing similar problems may profit thereby.

History

The C-E Raymond system of flash drying and/or incineration was first undertaken on a large scale at the West Side Plant of the Chicago Sanitary District in 1935. Subsequently, numerous installations have been made including other plants at Chicago and at Neenah-Menasha, Wis. (1937); Buffalo, N. Y. (1938); Springfield, Mass. (1940); Cuyahoga Falls, Ohio (1940); Duluth, Minn. (1941); Manitowoc, Wis. (1941); San Diego, Calif. (1943); Battle Creek, Mich. (1944); Sheboygan, Wis. (1946); Houston, Texas (1950); and Los Angeles, Calif. (1950). Large installations not yet under operation include those at Baltimore, Md.; San Francisco, Calif.; Waterbury, Conn.; Schenectady, N. Y.; Bethlehem, Penn.; and Washington, D. C.

In the C-E Raymond system, filter cake is mechanically mixed with a portion of dry material in a mixer of the pugmill type, and then violently agitated in the presence of hot gases in a cage mill. The mixture discharges into a cyclone collector. The sludge at about 10 percent moisture separates in the cyclone from the hot vapors and gases. A portion of the dry material is returned to the process and the remainder may be drawn off and disposed of in the dry form or burned in the furnace which supplies the hot gases for the cage mill.

This type of unit is also used for fertilizer production or for incineration in connection with standard garbage and refuse incinerators. The units at Watervliet, N. Y.; and Stamford, Conn., are of this type.

Buffalo

At Buffalo, N. Y., there are three flash drying units each designed to evaporate 5,833 lb. of moisture per hour with associated furnaces for incineration of the dried sludge. Soon after these units were started in operation, it was found that the sewage sludge contained a susbtantial proportion of sand which proved to be very

Nichols Herreshoff
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All sewage solids can be easily disposed of in a Nichols Herreshoff furnace, simultaneously, singly, safely, swiftly, surely and simply.

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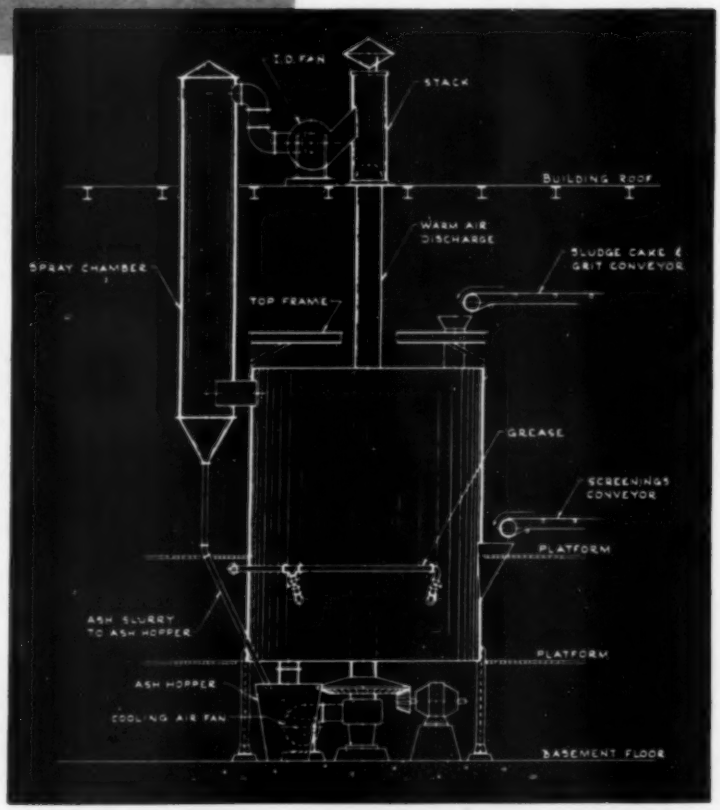
The secret of sewage treatment plants being "good neighbors" is good housekeeping and odorless disposal of the sludge, grit, screenings and grease in Nichols Herreshoff multiple hearth furnaces.



Schematic drawing illustrating the utter simplicity of destroying all sewage organics in a Nichols Herreshoff furnace.

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abrasive. Points of wear included mixers, the cage mills, the separating cyclones and in the fuel pipeline which transported the dried sludge from the flash drying system to the burners. Operating experiences have been described in the annual reports and by Velzy, Johnson and Symons.†

Drying towers were provided where hot gases from the furnaces are mixed with sludge before passing to the cage mill. These were lined initially with stainless steel plates which became distorted after a period of operation. Replacement of the buckled liners with a ceramic material poured in a wooden form proved to be a satisfactory solution to this problem.

The dry sludge cyclones were originally equipped with mild steel replaceable liners. It developed at Buffalo and elsewhere that this method of lining was uneconomical. The manufacturers made an intensive study of the problem and arrived at the conclusion that a gunite lining, consisting of trap rock and lumnite cement, was a satisfactory and economical protection for the interior of the sludge cyclones. Several of the cyclones at Buffalo have been lined with a ceramic known as "packing house floor tile," or with quarry tile.

The solution for the wear on the paddles in the mixers appears to be a paddle with easily replaceable abrasion resisting tip.

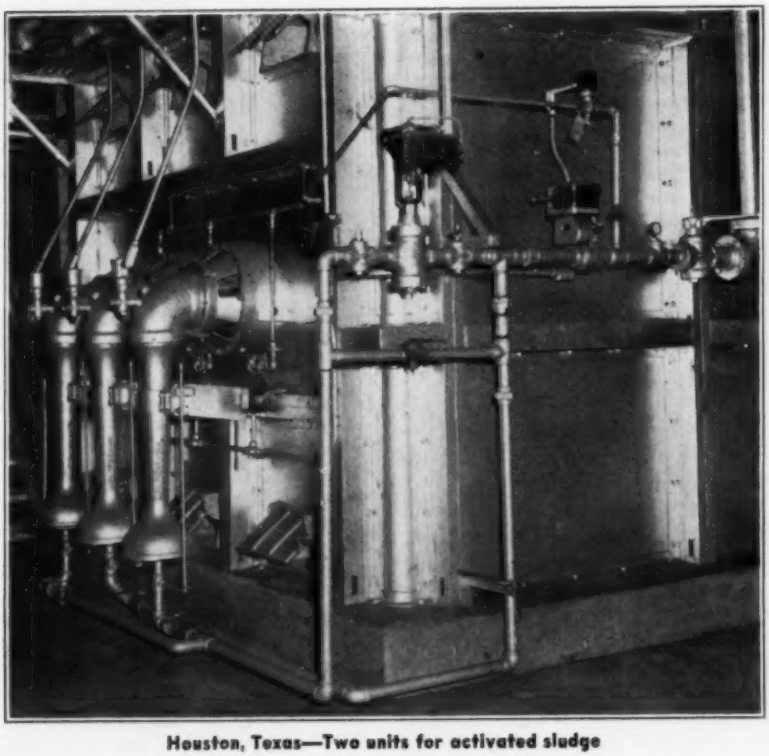
Changes made to one cage mill at Buffalo illustrates current standard practice. In order to provide for more economical maintenance, the housing was built to allow for rapid dismantling and provision made to pull the agitator mill out on rails for inspection or adjustment. The need for this was demonstrated as the rods on the rotor and stator were subjected to severe abrasion. As first rebuilt, the rods in the cage mill were protected with high manganese steel but these were expensive and wore out rapidly. A second development using a double, extra heavy, 1¼-in. steel pipe sleeve over a ¾-in. gave more economical results. With further experience, it is indicated that the most economical design is to supply 0.40 carbon steel bars and to build them up with stellite or other hard facing material as wear occurs.

The fuel pipelines initially installed at Buffalo have been removed and have not been used subsequently at other plants. The standard type of sludge feeder now consists of a duct from the drying cyclone to a screw conveyor which feeds the sludge burner.

The induced draft fans as originally installed were on the dirty air side of the ash cyclone. The fans wore rapidly and repairs and replacements were difficult to make. When these fans were moved to the clean air side of the ash cyclones, the wear due to abrasion by sand in the ash was largely eliminated.

The initial installation of pneumatic equipment for ash removal included a cyclone bag filter and vacuum pump. With the temperature of the ash at 1,100-1,113 deg. F., the bags in the filter burned out and the vacuum pump became plugged with ash, a problem solved by installing a second cyclone in place of the bag filter and a steam ejector in place of the vacuum pump.

†Sewage Works Journal, September 1940.



Houston, Texas—Two units for activated sludge

Springfield, Mass.

The unit at Springfield has a rated capacity of 10.5 tons per day dry weight of digested sludge solids per 24 hr. when drying sludge cake containing 67.5 per cent moisture with 50 per cent volatile dry basis. During the 10 years 1941-1950, inclusive, the unit was operated on the average of 1,411 hr. per year or approximately 5.6 hr. per work day for a 5-day week, while handling the total sludge production. The average moisture evaporated was approximately 750 lb. per hour of operation. The auxiliary fuel in the form of sludge gas used for burning the sludge amounted to about 650 cu. ft. per 1,000 lb. of moisture evaporated. This is reported for conditions in which there is an abundance of sludge gas at the plant and where it is not necessary to take particular care in the conservation of fuel at the incinerator.

During the years 1943 and 1944, the sludge was dried for fertilizer but in other years the market was not favorable enough to warrant drying operations and expense.

As in the case with Buffalo, the drying cyclones were initially lined with steel plates. They have subsequently been relined with a mortar of lumnite cement and trap rock. The life of the paddles in the sludge mixers has been extended by adding a facing of abrasion resisting materials by means of electric welding.

John P. McDonald, sewage treatment plant engineer, at Springfield, reports complete satisfaction with the installation after 10 years of operation. He states one of the advantages of this type of equipment is the facility with which it can be started up without undue delay in preheating or without burning fuel during nightly or weekend shut-downs. The practice of burning during the day shift only

and with no heating during the standby period has not resulted in evident damage to the furnaces.

San Diego, Calif.

The first C-E Raymond unit at the San Diego plant was placed in operation during 1943. This unit has a rated capacity to evaporate 3,500 lb. of water per hour. Enlargements to the plant which were commenced in 1948 included an additional flash dryer with a capacity of 5,000 lb. of water evaporated per hour.

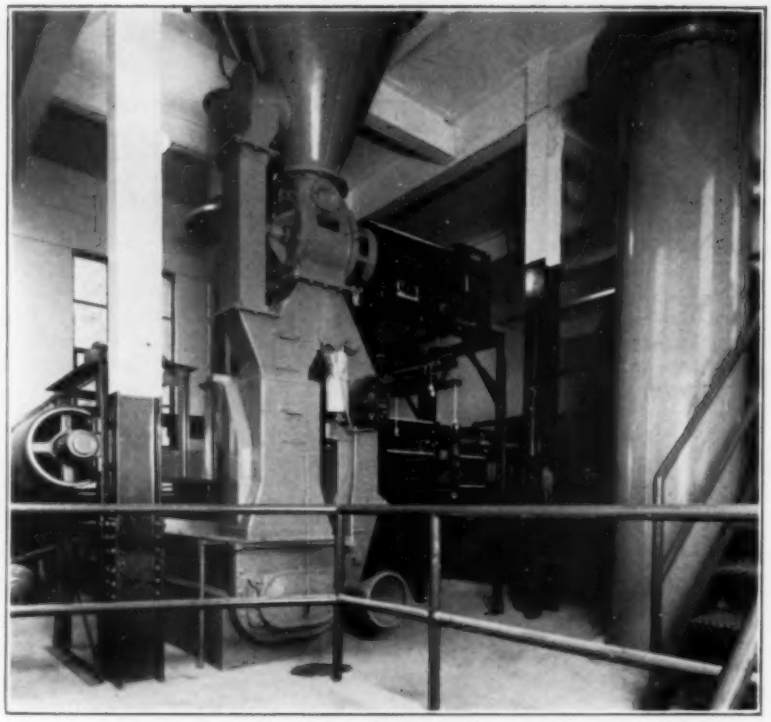
The experiences in operation at this plant due to wear from quantities of sand in the sludge removed have been somewhat similar to those at Buffalo.

One of the problems that has been peculiar to the San Diego plant has been the prevention of explosions which would occur from time to time during the shutdown period. In accordance with the manufacturers' recommendations, facilities have been provided to permit flooding the system with steam during shutting down procedure or at times of power failure. The same protection can be afforded by the injection of water through fog nozzles. The manufacturers have commented that this system, in common with all flash drying systems, is equipped with a relief vent on top of the cyclone. They state that this relief vent will safely relieve explosions of any kind and without any danger to the operating staff. This latter is evidenced by the fact that over 10 to 12 years' experience with operation of these plants there is no reported case of damage to the equipment or injury to an operator from such source. However, it is reported that these "puffs" are demoralizing to operating personnel and the manufacturers state that provisions for injection of steam or water is a simple and convenient way of rapidly cooling down the system without damage to the equipment or furnace and is a very desirable convenience. At San Diego, the injection is made at the entrance to the dryer cyclone and cage mill.

The new installation includes a reinforced concrete brick-lined exhaust tunnel and 150-ft. stack for removal of dryer gases. There have been several fires in the tunnel and lower part of the stack. It appears that the operation of water sprays throughout the length of the tunnel and at the bottom of the stack has eliminated this difficulty. It is reported that the trouble in the tunnel was due to build-up of grease from ¼ to ¾ in. in thickness. This matter of grease in the sludge is an ever increasing problem in the operation of sludge handling and disposal units since the end of World War II. It is generally believed to be the result of the increasingly wide use of detergents. The manufacturers report that this trouble is not confined to any one plant or one location but that it is rather general. A grease content in the dry sludge up to approximately 8 percent will give no trouble. However, when this percentage is substantially exceeded, the very low temperature volatile fractions of the grease are distilled off and will condense on any cool surface. If not continuously removed, it may be ignited at some time during the period of the shutdown of the system. To preclude such the safe thing to do is to clean this part of the equipment either continuously by the use of water sprays or periodically by scraping.

A further reference to this problem of grease accumulation is given in the discussion of the operation of the Los Angeles plant.

Eric V. Quartly, superintendent of the San Diego sewage treatment plant, reports that while many operating problems have been experienced with the flash dryers during past years, he does not wish to convey the impression they are unsatisfactory for the purposes intended. On the contrary, he states these units are giving excellent service at the present time.



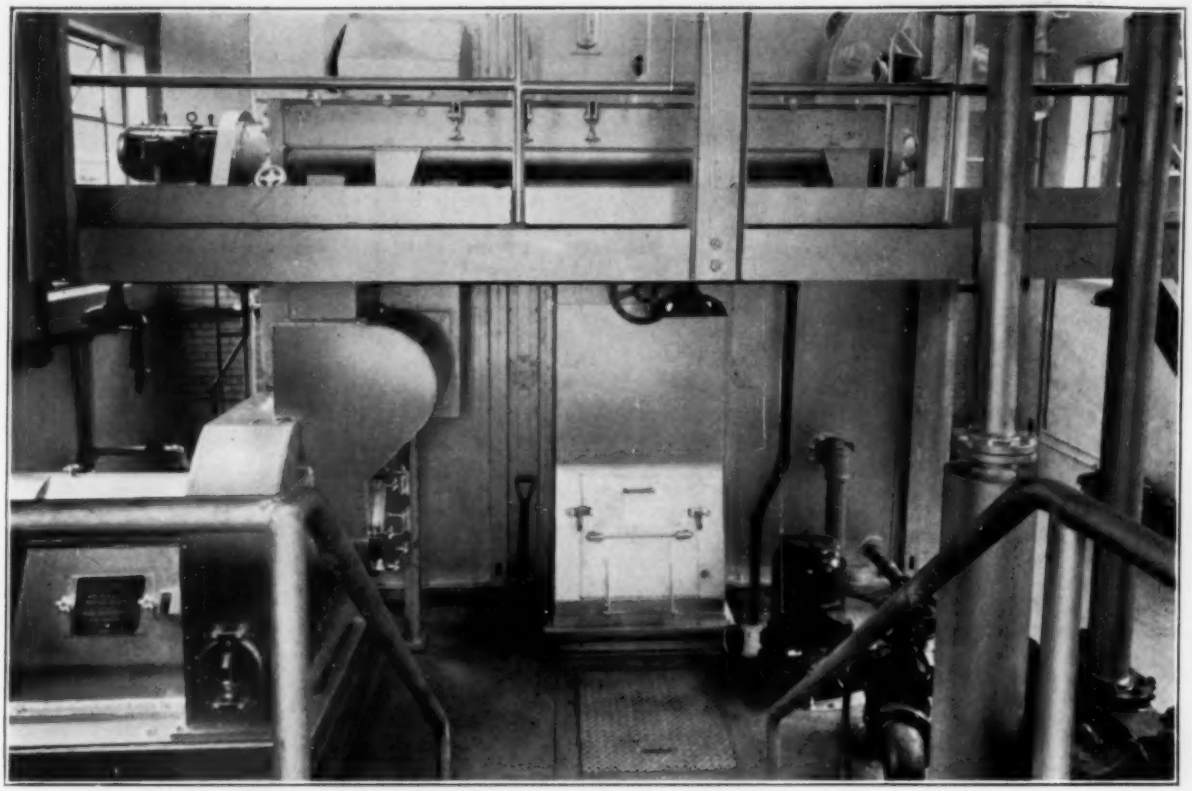
Stamford, Conn.—Flash drying system in connection with garbage and refuse incineration

Los Angeles

The flash drying and incinerating equipment at the Los Angeles Hyperion plant includes four units each having a capacity to evaporate 22,500 lb. of moisture per hour from sludge cake containing 25 percent solids. Each unit was specified to be capable of incinerating all or any portion of the material dried by it.

The equipment was first placed in operation during August, 1950. In a recent operational test conducted by the City, the average evaporation was 22,280 lb. of water per hour while producing fertilizer at the rate of 8,670 lb. per hour with an average filter cake load of 31,700 lb. per hour. The dryer inlet temperature was 1,112 deg. F. as compared with a design temperature of 1,300 deg. F. It is possible that if the design temperature was maintained at the dryer inlet, the evaporative capacity would be well in excess of the guaranteed figure.

During the month of May, 1951, the dryers reduced all of the filter cake produced at the plant to fertilizer amounting to 4,000,000 lb. for the month (moisture content 7 percent). Since the dryers were operated for only 23 percent of the time, there was no need to operate them at their rated capacity. The average moisture evaporated was 14,550 lb. per dryer. The dryer units at this plant have indi-



Cuyahoga Falls, Ohio—Small flash drying and incineration unit for handling raw sludge

cated that they can take care of all of the sludge produced on a design basis and with one spare unit.

As at the San Diego plant, there is some evidence of accumulation of grease which appears to have occurred when the digested sludge contained a reported average of 15 percent grease. Recently, the temperatures within the digestion tanks have been raised from an average below 90 deg. to about 95 deg. At the higher temperature, it appears that the grease content in the digested sludge will average approximately 5 percent. It is hoped that this will eliminate in large measure the grease problem on the walls of the flash drying equipment.

Summary

GENERAL. Equipment handling sewage sludge should be so designed as to resist wear from the abrasive particles contained therein. Parts subject to wear should be readily replaceable or provision made to build up the worn parts with abrasive resisting material.

PREHEATERS. Adequate provision should be made for cleaning, maintenance, and repair of preheaters in connection with flash drying furnaces.

MIXERS. The mixers designed for mixing dried sewage with wet sludge cake should have abrasive and corrosion-resisting liner plates. The paddles should be of meehanite or other steel alloy capable of resistance to wear at high temperatures. Shafts and paddles should be readily replaceable and it is desirable to supply the paddles with easily replaceable abrasive resisting tips.

CAGE MILLS. The inlent end of the cage mill should be lined with a corrosion-resisting alloy. The cage mill should be of quick-opening design in which the rotor and pedestal may be rolled back on a track thus facilitating the replacement of liner plates and the replacement of cage bars.

INDUCED DRAFT FANS. These fans should be installed on the clean air side of the ash cyclones where practical.

DUCTS. The ducts and pipes carrying sludge in suspension should be fabricated in easily removable sections. The bends should be provided with removable wear backs lined with abrasive resisting material such as chrome ore.

PURGING SYSTEM. A suitable system of water or steam purging for prevention of explosions in the system should be provided.

CYCLONE SEPARATORS. A lining is required which will resist abrasion. A 2-in. gunite mixture of lumnite cement and trap rock appears to be suitable for this purpose.

STACKS. It appears desirable to line chimneys taking the discharge from the flash dryers and incinerator with firebrick for at least the lower ⅓ of their height. Consideration should be given to the fact that occasional high temperatures may occur in the operation of incineration equipment.

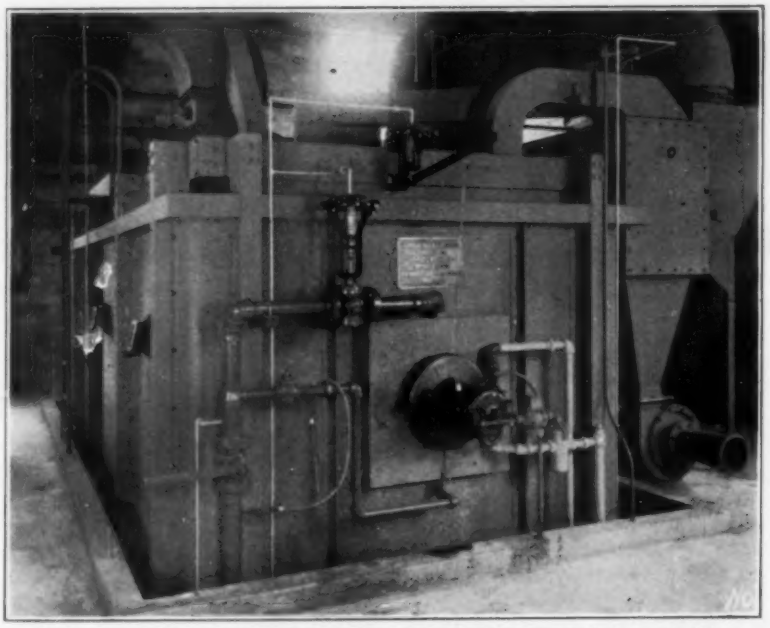
FLY ASH REMOVAL. Fly ash may create a serious problem in the gas discharged from the fly-ash drying systems unless appropriate means are provided for its removal. It has become increasingly necessary in the case of new installations to comply with stringent fire, smoke and air pollution ordinances. Enlarged ducts, settling chambers or inertia separators seldom would prove to be satisfactory.

Mechanical dust removal equipment such as the Multiclone type as manufactured by Western Precipitation Corp. or the fly ash collectors using the Van Torgeren system as manufactured by Buell Engineering Co., or the Thermix Controlled Multi-

Springfield, Mass.—Drying and incineration units for digested sludge

Clone type as manufactured by the Prat-Daniel Corp. usually afford satisfactory results for this service. However, in some cases, a higher degree of treatment must be provided for the removal of fly ash, such as electrostatic precipitation.

This latter type of equipment must be carefully designed to permit access for cleaning. If continuously high efficient removal of fly ash particles and smoke is required, sufficient units for fly ash removal must be provided so that one unit may be taken out for repair and maintenance.



Sheboygan, Wis.—Flash drying system for producing digested sludge fertilizer

Acknowledgment

Acknowledgment is gratefully made for data supplied by John P. McDonald, Sewage Treatment Plant Engineer, Springfield, Mass.; Eric V. Quartly, Superintendent, Sewage Treatment Works, San Diego, California, and to C. W. Gordon, Manager, Flash Dryer Division, Combustion Engineering-Superheater, Inc.

How A Sewer Contractor Cuts Handwork

by RAY DAY

Technical and Scientific Writer

AN INGENIOUS Utah pipeline and sewer contractor, with a firm conviction about the type of mounting his excavating equipment should have, has practically eliminated expensive hand labor from extensive sewer construction activities under his supervision. Eldon Kloepfer, of the Logan, Utah, construction company bearing his name, is the man with the idea. How well it paid off can best be told by the following incident.

On a recent job, a lateral sanitary sewer line had to be cut through a point where a sidewalk, four high-pressure water lines, a gas main and two telephone cables intersected the ditch, all within 25 feet. Kloepfer's machine handled the assignment in less than one-half hour, without a single shovelful of hand excavation being turned.

Kloepfer got his idea when he saw a Bucyrus-Erie "Hydrohoe" demonstrated near Salt Lake City, and noted the unusual measure of control and flexibility possessed by the machine. Here was exactly what he needed for much of the tedious, time-consuming, expensive hand-labor work in many of his operations—particularly lateral construction.

Kloepfer turned his mind to the problem of how to mount the machine so it would get into many of the places where this type of work is being done. One of the most troublesome problems in the northern Utah area is the presence of marshy, quaking bogs where the groundwater table is high. These places can quickly mire a machine on conventional truck mounting. Why not pick the Hydrohoe up off its truck mounting and set it down on the rear bed of a war-surplus halftrack? The more Kloepfer thought of the idea, the more it appealed to him.

With the Hydrohoe purchased,

"HYDROHOE" starting one of the lateral excavations—the only machine that could tunnel under the sidewalks

BUCKET of the "Hydrohoe" starting under a sidewalk. Working from first one side and then the other, the trench is quickly tunnelled through

Kloepfer put his plant into action. The mounting consisted of a war-surplus White half-track, which was picked up in excellent condition. A heavy steel bedplate was laid over the rear end of this machine, and the Hydrohoe, with its Ford engine and hydraulic pump equipment, was centered over the bed. The work was done in Kloepfer's shop by mechanics who ingeniously contrived a 10-bolt mounting. Should Kloepfer ever want to take the machine off the halftrack, he can replace it on its conventional truck mounting by loosening the ten bolts, lifting the machine over to the new mounting, and fastening it down again.

Idea Works Nicely

Kloepfer's idea has worked beautifully. He estimates that a labor force equal to at least 5 or 10 men has been eliminated from typical sanitary sewer construction contracts. The halftrack-mounted Hydrohoe has proved especially suitable for digging lateral ditches in those hard-to-get-at places. If both sides of a sidewalk are accessible to the ⅜-yard digging bucket on the machine, it can dig a trench quickly and easily *under* the concrete walkway, leaving enough dirt bridged to support the structure safely. Accompanying pictures show such an operation getting under way.

The controls on the Hydrohoe are exceptionally sensitive, and a good operator like Ralph Blotter, who runs the rig, can feel a pipline the minute the teeth come in contact. Accidental breakage of water or gas lines has been negligible in relation to the amount of work perfomed by the machine. And yet, according to Kloepfer, the machine has a very desirable power reserve which comes in handy whenever tough clays, gravel and other hard-to-dig formations are found.

It was recently necessary, for example, to dig through an old abandoned 3-in. steel line which was still in fair condition despite its long abandonment. Since there was no acetylene cutting torch on the rig at the time, the operator simply hooked into the pipe with his bucket and put the hydraulic retracting mechanism to work. The pipe was pulled out quickly and easily.

The unconventional halftrack mounting has absolutely whipped the marsh problem. During the winter months, when conditions underfoot are muddy and bad, Kloepfer's men have been able to take the machine into places impossible to reach with trucks. The Hydrohoe is sufficiently light so that the halftrack mounting floats its weight over the surface of the ground without mirring, or even without excessive penetration into the soft footing. The machine has the ability to get into a job and get out fast.

On lateral work it is not uncommon for the machine to start from a property line, dig a trench under a sidewalk and curb, and out beyond all intercepting utilities lines to a sewer connection near the center of the street in about 30 minutes. The Hydrohoe with its operator and two men have installed up to 20 complete laterals in a shift's time. The only expense for this operation, aside from the labor and depreciation on equipment, is from 7 to 15 gallons of gasoline which the machine will use in a 9-hour shift.

The telescoping boom and other control features on the Hydrohoe, coupled with the unique mounting which lets the machine get in where the work is, has given Kloepfer a head start in bidding this type of work.

Other Equipment Used

Over the years Kloepfer has built up an impressive lineup of sewer and pipeline construction equipment. For heavier excavation on mainline trenches, where hard digging is a problem, Kloepfer has two Bucyrus-Erie 22-B dragshovels. For lighter excavation, he uses an Austin-Western Badger, along with the halftrack-mounted Hydrohoe. For backfill work, there is an International TD-9 and TD-18A tractor and a Caterpiller D7 bulldozer. An Austin-Western motor grader, on which a dozer blade is mounted, is used for backfill, as well as for road reconstruction work over certain areas through which pipeline work has passed. Kloepfer also has water wagon equipment, dump trucks, and pickups.

Importance of Two-Way Radio

The entire outfit has been completely equipped with Motorola two-way radio communication. This has helped greatly to boost general efficiency by keeping key men and crews in touch with each other.

Kloepfer Construction Co. is currently busy on a 25-mile sanitary sewer job which is being done in Salt Lake County for Sanitary Sewer District No. 1. The job includes vitrified clay, concrete and Transite pipe, from 4 to 12 inches in diameter. Average trench depths are 10 feet, with an 18-foot excavation maximum. Formations through this job have consisted principally of boggy, wet sand and hard, blue clays.

According to Eldon Kloepfer, all of his equipment has come in very handy in hurrying the work along, even with heavy ground water conditions. And one of the handiest machines of all is the halftrack-mounted Hydrohoe.

Kloepfer summed it up in a nutshell as he smiled and said: "Now that we have this machine and know what it will do, we wonder how we ever got along without it. We wonder what we'd do if we ever had to go back to the old hand-labor methods. No class of labor on a job is quite as problematical as hand labor."

Garbage Grinder Experiences, Jasper, Ind.*

by FRANK D. WRAIGHT

Chief, Sewage Disposal Section, Indiana State Board of Health, Indianapolis, Ind.

THE CITY OF JASPER has a population of approximately 6,200 and is located in the southeast section of Indiana on the Patoka River. During prolonged dry periods, there is no flow of water in the Patoka River except that which is discharged from the sewage treatment plant. Most of the factories are dry industries with the exception of a poultry packing plant. Over 92 per cent of the residents own their homes which was one of the factors that made practical, community-wide installation of household garbage grinders. In 1949, Jasper was faced with abating pollution of the Patoka River and also finding a suitable method of disposing of barbage.

Because the garbage grinder would eliminate the garbage can and make possible a sanitary means of disposal at a reasonable cost, it was decided to proceed with the community-wide installation of the grinders and to construct a Sewage Treatment Plant designed to treat the waste from such installations. The Indiana State Legislature enacted a bill permitting the issuance of revenue bonds for the purpose of installing household garbage-grinders and providing the municipality with authority to establish such a project.

In March, 1950, the installation of garbage grinders was started and on August first there were approximately 730 grinders installed and garbage collection ceased. At the present time there are approximately 1,000 garbage grinders installed and practically all new houses are so equipped.

Inasmuch as there was no precedent for the design of the sewage treatment facilities, it was necessary to make some speculative estimates. Units which are affected principally by volume of flow were not increased over conventional design. The aeration tanks were increased by 50 per cent; the digester capacity was increased by 57 per cent; and the sludge drying bed area was increased by 60 per cent.

Table 1 shows how the average data for 1954 compares with the basis of design as well as the capacities of certain treatment plant units. The actual average flow is less than one-half the design flow and the population is a little more than one-half the design population.

Originally a 500 cfm blower powered by a dual fuel gas-gasoline engine and an electrically driven 500 cfm blower were installed. The gas engine was operated on gasoline, as sludge gas was insufficent. As there were times during which the blowers were inadequate, the gas engine and blower were replaced with an electric motor and blower to make an additional 1,000 cfm of air available at all times. This has solved the air supply problem.

Table 2 shows the effect of the number of garbage grinders on the B.O.D. and suspended solids of the raw sewage. Even though there were 150 more grinders in 1954 than in 1951, the total pounds of B.O.D. and suspended solids were slightly less. This is probably due to the fact that intense rain occurred during the 1951 survey and the solids which had accumulated in the lateral sewers were flushed out during the rain.

There was a significant increase in the raw sewage B.O.D. and suspended solids as a result of the increased use of residential garbage grinders (Table 3). No attempt has been made to calculate a value which would show the per capita contribution of ground garbage. The data collected in wet weather indicates a flushing of deposits from the sewers.

The following treatment efficiency averages for 1954 indicate the satisfactory results obtained:

Item	Per Cent Removal	
	Primary Treatment	Over-all Treatment
B.O.D	33	93.2
Susp. Solids	67.7	97.1

A comparatively high removal of suspended solids was particularly gratifying.

Table 4 indicates the daily variation in mixed liquor dissolved oxygen. Usual operation requires that only the 1,000 cfm blower be operated during the weekend with the addition of the 500 cfm blower during the week. This operation has maintained the dissolved oxygen content within reasonable limits.

Prior to May, 1955 all three aerators were in use. Based on aerator volume the pounds of B.O.D. removed per thousand cubic feet was rather low, approximately 16 lb per 1,000 cu ft. Since the first part of May, 1955, only two aerators have been in use with no apparent loss in the over-all removal of B.O.D. and suspended solids. Mixed liquor solids average 2,500 p.p.m., which is higher than carried previously. During this same month 23.5 lb of B.O.D. were removed per 1,000 cu ft of aerator tank volume.

*Reprinted from Sew. & Ind. Wastes, Vol. 28, No. 1, p-44 (1956)

TABLE 1

—Comparison of Operating and Design Data

Units	Data	
	Design	Operating (1954)
Population	10,500	6,200
Flows (mgd)	1.0	0.460
Grit chamber		
Comminutor		
Sewage pumps [4] (gpm)	2,200	
Raw sludge pump (gpm)	100	
Return sludge pumps [2] (gpm)	350	
Primary settling tanks [2] (surface rate, gal/sq ft/day)	1,040	480
Aeration tanks [3] (detention time, hr.)	7.8	16.9
Blowers [3] (cfm)	1,000	1,500
Final settling tanks [2] (surface rate, gal/sq ft/day)	750	345
Digesters [2] (cu. ft./capita)	6.6	10.8
Sludge drying beds [8] (sq ft/capita)	3.1	5.0

TABLE 2

—Effect of the Increasing Number of Grinders on B.O.D. and Suspended Solids

Grinders (no.)	Flow [1] (mgd)	B.O.D. (ppm)	B.O.D. (lb)	Susp. Solids (ppm)
0	0.407	151	510	114
850	0.502[2]	387	1,620	420
1,000	0.446	392	1,460	392

[1] Average flow.
[2] Increased flow due to rain.

TABLE 3

Per Capita Waste Discharge

Month	Grinders (no.)	Determination (lb per day per capita)				
		B.O.D.	Total Solids	Total Vol. Solids	Susp. Solids	Susp. Vol. Solids
1950						
Mar.	80	0.12	0.39	0.18	0.19	0.14
Oct.	785	0.18	0.41	0.26	0.20	0.16
1951						
May	850	0.31	0.88	0.59	0.34	0.29
1954						
Oct.	1,000	0.32	—	—	0.34	—

Unfortunately, few data are available which would indicate the quantity and quality of the sludge pumped to the digester. However, based on the suspended solids removed and allowing a 20 per cent loss in the secondary process, it has been calculated that 1 lb. of solids produces from 8 to 10 cu ft of gas.

After treatment plant operation began, it was discovered that it was impossible to use both return sludge pumps and maintain the desired solids concentration in the mixed liquor. The inability to return sludge was due to the fact that the sludge division box was installed at a lower elevation than specified in the design, resulting in a bottleneck in the return sludge system. The box was raised approximately 3 ft solving this problem.

The sludge index and mixed liquor solids curves (Fig. 1) illustrate the conditions existing prior to raising the division box. These curves are based on Professor Bloodgood's statement that the sludge index converted to parts per million should be equal to or higher than the return sludge concentration. During this period of operation, considerable difficulty was occasionally encountered in producing a settleable sludge.

TABLE 4

Daily Variations in Dissolved Oxygen

Days	Dissolved Oxygen (ppm)		
	Min.	Av.	Max.
Mon.	1.1	1.2	1.6
Tue.	1.4	2.3	3.3
Wed.	1.3	2.9	4.7
Thurs.	1.1	1.6	3.6
Fri.	1.1	2.1	4.3
Sat.	1.4	2.6	3.6
Sun.[1]	—	—	—

[1] No determinations made.

After eliminating the return sludge bottleneck, it was possible to operate under the conditions shown in Figure 2. The mixed liquor solids increased toward 2,000 ppm and the sludge index improved.

Sewer System

The Jasper sewer system contains approximately 15 miles of combined and sanitary sewers. New sewers are designed for sanitary flow. However, the original system, which was constructed in 1910 and expanded after 1925, is a combined system. Grades vary from 0.16 per cent for the 12-in. trunk sewers to 7.25 per cent on the 6-in. lateral sewers. Considerable building is now taking place north and east of the city, and a large area recently has been annexed whiich will add several hundred residen s to the sewer system.

Before the garbage grinde, project was initiated several manholes were selected as check points to observe the sewer outlets from various sections of the city. The purpose was to determine whether or not sludge deposits would increase with an increase in garbage grinders.

A recent inspection of the outlet of an 8-in. sewer on a .61 per cent grade, with a theoretical velocity of 2.5 ft per second flowing full, revealed no excessive sludge deposits. Originally there were 49 garbage grinders on this lateral; now there are 70 to 80 units. Principal sewer maintenance problems are tree roots and infiltration.

Summary and Conclusion

1. Air requirements per pound of B.O.D. removed are more than were anticipated in the original design, which was 1.4 cu ft per gallon of sewage.

2. The increase in the number of garbage grinders produced a noticeable increase in B.O.D., suspended solids content and volatiles. Data collected in wet weather indicates deposits have collected in the sewer system but are readily flushed out during a rain.

3. B.O.D. removals are not exceptional; however, the percentage of suspended solids removed in the primary settling tanks is good.

4. With the addition of a 500 cfm blower it was possible to maintain a reasonable D.O. content in the aerators at all times. It now appears possible to operate effectively using only two aerators.

5. Gas production is considerably higher than found in sewage treatment plants not handling garbage. In

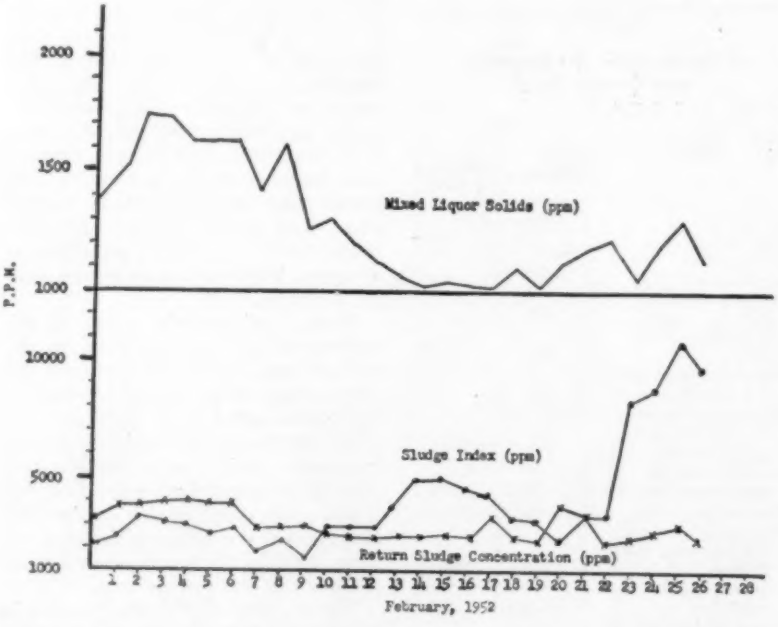


FIG. 1—SLUDGE and mixed liquor solids prior to increasing the return sludge volume.

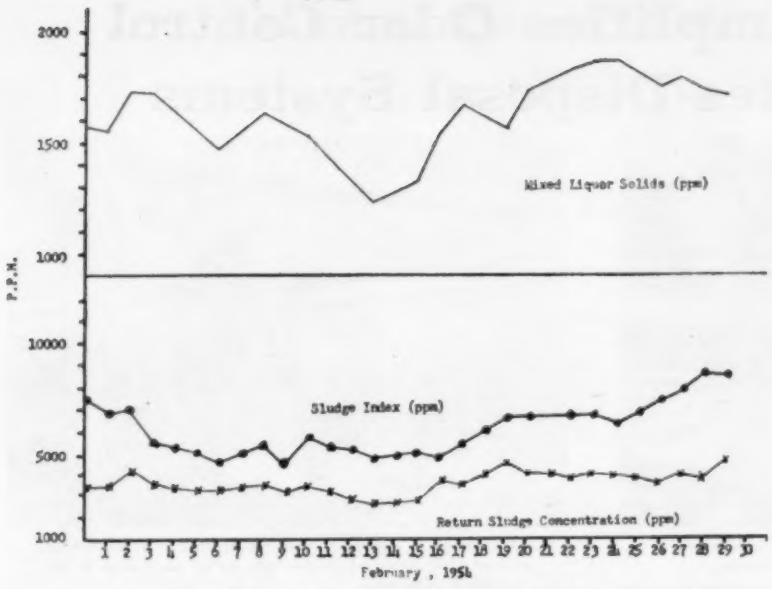


FIG. 2.—SLUDGE index and mixed liquor solids after increasing the return sludge volume.

many cases it may be 80 per cent higher.

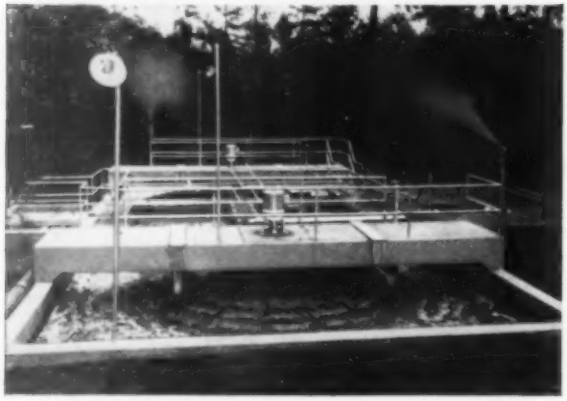
6. Sludge deposits in the sewer system are not a problem.

The system of community-wide installation of garbage grinders has provided a sanitary means of garbage disposal for Jasper and has been a big step in improving the general sanitation in the city. This system is not considered the ultimate in garbage disposal because it would be difficult if not impractical for some cities. The job of disposing of thrash remains and this can create a sanitation problem in itself.

After five years of operation it can be stated that the disposal of garbage by the community-wide installation of garbage grinders has been successful for Jasper. The system has had certain operating problems; however, they have been little different from those encountered at any activated sludge sewage treatment plant.

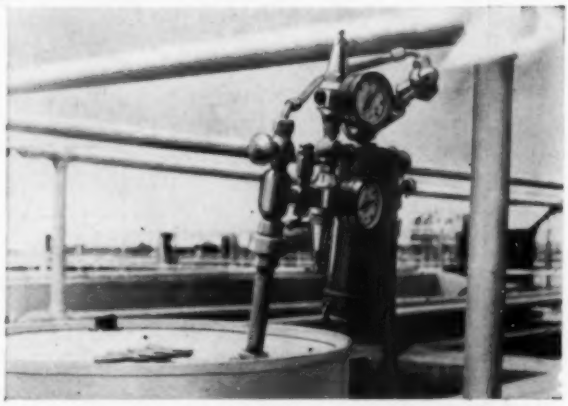
Airkem Simplifies Odor Control For Wastes-Disposal Systems

1. Vaporized Airkem solution from application unit counteracts airborne odors from primary settling tank area.



2. Airkem spray heads are located at extreme right and left of activated sludge tank. Time clock controls application heads for evening operation.

3. Drum application unit, simplest form of Airkem installation, is shown here at municipal sludge lagoon.



4. Close-up of applicator head mounted on drum of Airkem liquid. This simple equipment plus an air compressor is the complete installation.

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WS-5

Counteraction of Sewage Odors*

by NICHOLAS POST

Airkem, Inc., New York, N. Y.

IN THE PRACTICAL field of air pollution abatement in the past, the destruction of odors has often had the aspect of a hopeless task. The field of physical and chemical destruction of odors has been explored endlessly. Mechanical equipment for this purpose has proved to be inadequate and costly And, while practically every known combination of chemicals has been tried at one time or another in an attempt to destroy odors by chemicals reaction, most chemicals that are known to be effective as powerful deodorants against air-borne odors are toxic to human beings in the concentrations required for odor destruction in the atmosphere.

The treatment of sewage and industrial wastes has become an extremely important aspect of modern living and the designing engineers and operators of modern sewage treatment stations are to be commended on the excellent work they have done in attempting to control odor nuisances. There are still odor-control problems to be solved, however, in the handling of sewage for, while treatment and disposal are conducted under careful bacteriological control and advanced engineering design, some plants are subjected to the most complex and obnoxious mixtures conceivable. The liquid wastes from industrial activity alone are seemingly endless in variety. These wastes come from dye works, chemical plants, synthetic rubber plants, oil wells, refineries, gas plants, milk condenseries, paper mills, slaughter houses, glue factories, woolen mills, breweries, food products plants, and many other industrial establishments.

In wastes from most of these sources there is adequate organic matter of nitrogenous or sulfurous nature to give rise to the noxious products of biological decomposition. From the standpoint of odor, the worst of these gases are sulfides, mercaptans, indoles and amines. In addition to organic products, the waste waters from many establishments contain dissolved gases of malodorous quality that are little affected by the natural forces of self-purification in the water course or lake. These not only affect the water supply but may also contaminate the air for miles to degrade the surrounding commercial shorelines, bathing beaches and resorts. Many odorous industrial plants are removing odorous effluents from their stacks by the use of cyclone washers or scrubbers and chemical reaction. Unfortunately, a good many of these wastes are not readily oxidized or consumed as organic food, and treatment for odor by use of chemicals may create new odor problems.

Odor Perception

Since hydrogen sulfide, methyl mercaptans and methyl amines are all odorous offenders, one might conclude that the elimination of hydrogen sulfide would be the first line of attack. It is well known that hydrogen sulfide is a very toxic material and there have been reports that some sewage treatment plants have dispersed sufficient quantities to cause physical damage to plant equipment. A condition of this nature, of course, should be corrected at once. In sewage odor perception, however, hydrogen sulfide is not always the primary problem.

In the field of odor perception there are four facts of primary importance which must be taken into consideration, even though they cannot be demonstrated by chemical analysis. These are as follows:

1. Weak odors are not perceived in the presence of strong ones.
2. Odors of the same strength sometimes blend to produce a combination in which one or both of the components is unrecognizable.
3. In the presence of odors of constant intensity we rather quickly lose awareness of any odor at all.
4. Our like and dislike for any odor depends largely on association of the scent with pleasant or unpleasant experiences and impressions in the past.

Odor appraisals by the author of some 300 sewage plants in the Midwest, the Gulf Region, the Atlantic Coast and the West Coast indicated that hydrogen sulfide is not the typical sewage odor characteristic. The similarity of sewage odors was more noteworthy than any dissimilarity, in spite of variations in hydrogen sulfide. It was therefore concluded that combinations of methyl mercaptans, methyl sulfides and amines, in addition to indoles and skatoles, are the major offenders in sewage odor perception. When this combination of odors is in the air stream, there occurs what may be termed the "typical sewage odor." While this odor characteristic in all plants visited was very similar, it varied in intensity. Local conditions and types of treatment may increase or decrease any of the aforementioned odor combinations.

Odor Control Techniques

Methods now commercially available for control of odors by treatment of odorous air may be divided into four general classifications: combustion, absorption, use of odor modification, and counteraction. The first three methods, with their operating problems and limitations, have been described elsewhere in the literature, notably by Weaver[1]. The author is primarily concerned with describing the method of counteraction, previously treated by von Bergen[2].

Principle of Counteraction

A very limited number of scientists have directed their attention to the field of odor perception. Around the turn of the century, Hendrick Zwaardemaker, a Flemish scientist, discovered that two substances, odorous singly, may be inodorous together. Using a double olfactometer, he experimented with many pairs of odorous substances, introducing them individually to either nostril to measure the ratio of quantities required for neutralization or counteraction. By this method, all possibility of chemical reaction between the two substances was removed. Some of the recorded counteracting odors were cedarwood *vs.* rubber; rubber *vs.* wax; wax *vs.* balsam of Tolu; and paraffin *vs.* wax. It is important to note that the true neutralization or counteraction of odors leaves no overriding odor, pleasant or unpleasant. There is some confusion in both the technical and popular press regarding the terms "odor masking" and "odor modification" or "odor counteraction." Strong odors tend to mask weaker ones. If two odors are of about equal strength, a blend of the two is perceived or pos-

*Reprinted from *Sew. & Ind. Wastes*, Vol. 28, No. 2, p. 221 (1956)

sibly both are identified. If one odor is considerably stronger than the other, as a rule it alone is perceived. This is masking. On the other hand certain pairs of odors, in appropriate relative concentrations, are antagonistic; and, when the two are sniffed together, the intensity of each odor is diminished. This is counteraction. The field of odor control by counteraction, as developed today, is based on the signficant work done by Zwaardemaker. The development of odor counteractants has been a matter of pure research and many years have been spent in this delicate work.

There is no widely accepted classification of odors and, as a matter of fact, the description of odors usually depends on comparison. Sewage odors are complex groups of odors. It is unusual to obtain a specific odor from a sewage treatment plant and, even when this is the case, the odor may combine with transient odors in the surrounding atmosphere. For this reason waste odor counteractant formulations, although designed for specific odor descriptions, may contain complex groups of odor counteractants. There is no chemical method known for determining the effectiveness of odor counteractants. They are, however, successful in odor perceptive work and, in the last analysis, odor perception trials are the criteria for the effectiveness of any odor abatement method.

SYSTEM for counteraction of odors in sewage plant

Application of Odor Counteractants

The principle of odor counteraction deals with the molecules of malodor. In the process of odor perception the olfactory tract is so located that ordinarily only gas reaches it. Gas, of course, includes vapor. The sensitive areas are at the closed ends of channels that are readily penetrated only by diffusion, and the diffusion of solid and liquid particles of more than submicroscopic size is almost negligible. Accordingly, characteristic odors are rarely, if ever, produced by a smoke or mist of solid or liquid particles, however fine, except in the case of materials volatile enough to be smelled when only the vapor comes from massive forms of them. For practical purposes an odor is always a gas molecularly dispersed in the air in sufficient concentration to be above the threshold level of perception. For this reason, odor counteractants are most effective when vaporized and combined with the air stream by molecular dispersion. Regardless of whether the stream of odors is held to the ground by air inversion or is vertically or horizontally dispersed, the counteractant is carried with the malodor and is noticeably effective until the odor is dispersed beyond the range of perceptibility.

There are many sources of odor within the sewage treatment plant. Open grit handling areas, bar racks and screens, sedimentation areas, drying beds, sewage vents, manholes and lift stations may all become odorous. The odors from these sources expand by molecular dispersion in a rough range of five to one until the odorous pool is taken over by air movement. Further dispersal, mixing and dilution takes place during the variable air movements until the characteristic odor of sewage is perceived in the complaining area.

Odor counteractants are vaporized in much the same way by atomizing the counteractant into the air stream by means of a calibrated atomizing nozzle. These vaporizing points are usually located at the ground level, on the roof of a plant structure, and in the vicinity of the most odorous effluents. This provides vertical coverage from the bottom to the top of the odorous pool. The odor counteractants mix with the odorous air stream by molecular dispersion and air movements, and are designed to follow the physical behavior pattern of the odorous elements. Some odorous elements disperse beyond the limits of perceptibility rapidly; others are more tenacious and do not disperse as quickly, either horizontally or vertically. Many groups of odors continue to travel and vaporize for miles. Specific odor counteractants are designed to follow these physical dispersal patterns.

Vaporization of the liquid odor counteractant is accomplished by clean, compressed air (approximately 2 c.f.m. per gun). The liquid odor counteractant is stored in a drum in a convenient location and fed through small connecting lines to the vaporizing nozzles by air pressure. The operation is automatic and, once the installation is set up and balanced, requires little maintenance except for weekly filling of the containers. Odor sources, vaporizing at a continuous rate, are treated continuously. The atomizing equipment is simple, requires little or no service and is readily adaptable to any area. It is easy to install, no alterations are required in the process equipment, and no downtime is required for installation.

In one activated sludge plant with an average daily sewage flow of 12 m.g.d., two guns were mounted to vaporize in the area of the aeration tanks. Another gun was located at the grit removal chamber to take care of

the odors from this point and also those odors which might originate from the sludge drying beds nearby. A specific odor counteractant was used for these odorous components.

In a second treatment plant which treats the wastes from a population some 20,000 people plus the industrial wastes from a pharmaceutical laboratory, two guns were installed at the trickling filters to operate automatically. At this plant the odor is most noticeable during the late afternoon and early evening hours so counteraction is placed in operation only during these hours when the odors are most severe.

In a third treatment plant hydrogen sulfide escaping from a raw sewage inlet structure caused numerous complaints. A vaporizing gun was installed at the top of this inlet for atmospheric treatment. The enclosed area within the structure was not treated. It should be pointed out, however that, without its warning characteristic odor, hydrogen sulfide can be very deadly. It should never be treated for odor control until it has been discharged at a point where dispersal is sufficient to reduce the parts per million below the maximum permissible limits for toxicity.

Dispersion of Odors

The atmosphere surrounding a sewage treatment plant usually has great capacity to disperse odorous effluents. Under favorable weather conditions the odors from a plant will rise gradually as they flow downwind and the contaminants will be dispersed until only a negligible concentration prevails in the atmosphere. Under these conditions and under conditions of actual vertical dispersion, odors do not ordinally become an annoyance in the surrounding area. Unfortunately, there are many natural influences which arise to disturb this orderly dispersion. These adverse influences are aerodynamic and meteorologic. Wind flowing past a treatment plant generates a turbulence in the wake of the digesters and of the buildings. Turbulent masses of odor above and behind the plant are brought down to the ground in a spreading area. This is termed "downwash." Under these circumstances concentrations of odors may be very high an area close to the plant. If the odor escapes the downwash situation it may flow downwind and come under the adverse influence of terrain. Hills, valleys, bays and pockets may set up currents which entrap the odors. Thermal influences in the atmosphere play a large part in the over-all movement. Under conditions of air inversion large quantities of odors may be brought to the ground over a large area and sometimes held there for hours. The location of the treatment plant is also of great importance. It may be located in a deep valley or on level ground, in sparsely settled territory or a community where there are many obstructions to smooth air flow. These factors all affect the dispersion and the diffusion of odors, the reaction of the surrounding community to them, and are important to valid odor survey work.

The odor counteraction method of application is adaptable to favorable and unfavorable air movements. Under conditions of good vertical dispersion or rising horizontal dispersions the application can be cut off. Under conditions of air inversion or wind velocities that create building turbulence and thermal looping, the counteractant may be dispersed into the air stream. Many sewage treatment plants are located in areas where the prevailing wind may be away from the populated or residential areas. To meet such conditions, wind control devices have been designed that automatically apply the odor counteractant when the wind is in the direction of the complaining area and stop the application when the wind direction is towards an unpopulated, or non-complaining, area.

Public opinion is an important factor in air pollution control and lack of an understanding public relations attitude towards the problem of air pollution is a serious matter. Good relations with a general public are extremely important for an aroused public is an unreasonable public, and an unreasonable public can cause excessive expenditures. It is, therefore, essential that industries and municipalities survey their positions to determine the most advantageous course of action in reference to air pollution control.

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VI. INDUSTRIAL WASTES

PROBLEMS in the disposal of used water exist in most of the process industries. Government surveys indicate that there are more than 10,600 industries discharing water polluting wastes. Of these approximately 3,000 are known to be treating wastes to some degree and of approximately 7500 more plants with liquid wastes, perhaps 2500 are organic in nature equivalent to a population of 60 million persons.

The quantities of these wastes vary widely sometimes running as high as 50,000 gallons per unit of production. When consideration is given to the volume and strength of the various wastes from industry, it becomes readily understandable that industrial waste pollution of natural water supplies is a serious problem.

Combined Treatment

According to H. H. Black of the U. S. Public Health Service, "There are many instances where the residual wastes from a manufacturing process can be most economically treated along with domestic sewage." This "combined treatment" approach to handling industrial waste treatment has been growing throughout the country. Combined treatment usually causes fewer problems in large municipalities where the quantity of sewage provides adequate dilution. In small cities, the opposite condition may exist.

Not all industrial wastes can be taken into the municipal sewers and treated in the municipal sewage works. In short, certain wastes are not acceptable in municipal sewers. Those wastes which, by themselves or by reaction with other wastes, interfere with the normal operation of the sewers or sewage treatment processes cannot be taken into the sewers.

Unacceptable wastes include explosive and flammable substances and substances which liberate dissolved gases of corrosive nature or are otherwise corrosive sewers or treatment works structures. Toxic substances must be excluded unless they are diluted to concentrations below the level which will not adversely affect biological activity at the treatment works. Petroleum wastes also are generally unacceptable.

Industrial Waste Surveys

Where industry exists in a municipality, and there is problem of treatment of industrial waste involved, it behooves both the municipality and the industries to cooperate in an industrial waste survey.

In any industrial waste survey, the purpose is not to persecute industry but to establish the extent of the problem and the solution. The initial step in an industrial waste survey is to obtain adequate publicity to the general public and the industries, emphasizing that the cooperation and aid of industry is the paramount consideration.

The second step is to list and classify all industries eliminating those which have no waste, or those which present no problem to treatment. Other classes should be listed in order of known relative strength or importance. The next step is to confer with the individual industries and set up a program of actual investigation, sampling and analysis.

Pretreatment

In some instances, industrial wastes are not acceptable unless they receive some pretreatment. Pretreatment is particularly valuable as a means of reducing the load on the municipal plant. Screening is the simplest form of pretreatment; it is particularly applicable to canneries, tanneries, and paper mills. Settling with or without chemicals is useful but present problems of sludge disposal for the industry. If grease is a problem, it should be removed or recovered.

When industrial wastes are taken into the municipal sewer system, it is highly desirable that industry does not dump wastes. Rather, wastes should be discharged continuously over the day, or if possible discharged during the night hours when the domestic sewage concentration and volume is low. The control of waste discharge is possible by means of instrumentation.

Charges for Industrial Wastes

When industrial wastes are discharged to a municipal sewer system and treatment works, there is always the question of how shall the industry be charged for the treatment of the wastes. In some cities, the payment of real estate taxes are the only charges made to industry, but such taxes pay only for a waste volume commensurate with the property value and a waste strength no more than average domestic sewage.

In recent years, the theory of sewin effect in one third of the cities in this country of over 5000 population. Such charges are based on the theory that persons who use or have the benefit of sewage treatment should be charged for the service in relation to the benefits. Application of this theory to industrial wastes is not simple.

Four Types of Formulas

There are four basic formulas by which industries have been charged for wastes discharged to the municipal sewage works. These formulas are briefly: (1) The Flat Rate Formula, (2) The Quality-Quantity Formula, (3) The California Formula and (4) The Joint Committee Formula.

The Flat Rate Formula is based on same cost per unit, e.g., unit of production, floor space, volume of waste, volume of water used, time or type of industry. The Flat Rate Formula is generally used in the smaller communities.

The Quality-Quantity Formula is an attempt to obtain a more appropriate basis of charge. This type of formula is applied to wastes higher in concentration (or volume) than that considered normal for the municipality—on the theory that these wastes impose operating costs greater than will be paid for by taxes or flat rates.

The California Formula, as proposed by the California Sewage and Industrial Waste Assn., was an effort to overcome the inherent fault of the Quality-Quantity formulas namely, their strictly local application. The California Formula combines consideration of both cost of treating the waste and taxes paid.

The fourth formula was developed by the Joint Committee of ASCE, Am. Bar Assn., AWWA, NARUC, MFDA, FSIWA and APWA. The basic difference between this and other formulas is that it charges some of the costs of operation to non-users, i.e., to property. The charges are computed on the basis of (1) collection system and treatment plant and on cost of operation, maintenance and replacement costs and (2) fixed charges. The proportion of these two costs to be borne by users and by properties is determined for each of the two parts of the system (collection and treatment). The application of this formula is quite complex and is feasible only in large cities where there is an adequate technical staff.

These formulas, with examples and applications have been set forth in an article in the Equipment and Data Section of the Sept.-Oct. 1956 issue of *Industrial Wastes.*

Requirements for Establishing Industrial Waste Ordinances

by DEAN M. TAYLOR

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INDUSTRIAL WASTES and domestic sewage are two of the principal causes of the recognized water pollution problem in this country. Both types of wastes are man-made and can be controlled.

Industrial wastes discharged to public sewers constitute a large proportion of the total flow from industry. It is this segment of the total which can be controlled on a local level by the rules and regulations commonly known as industrial waste ordinances.

Most industries in this country are located in or near political subdivisions which have sewer systems. A U. S. Public Health Service report[1] stated that there were 11,811 municipalities having sewer systems, with about 56 per cent having sewage treatment plants, most of which were receiving industrial wastes to some extent. A survey by the National Association of Manufacturers of more than 3,000 industries indicated that 69 per cent of the industries discharged all or a part of their wastes into municipal sewage works. These facts point to the common problem facing industries and municipalities in waste disposal.

Industry naturally wishes to dispose of wastes at the lowest possible cost. This can usually be done by discharge to the municipal waste disposal system. Most industries in incorporated areas feel that it is the responsibility of municipal government to dispose of their water-carried wastes. Most municipalities are willing to accept this responsibility, provided the industrial wastes are acceptable for discharge to the municipal sewage disposal facilities. When the quantities of industrial wastes are much greater than those of domestic sewage, there are usually problems of jurisdiction and cost. These problems, however, can be solved with equity.

Every industry has the option of treating its own wastes and discharging them to public watercourses. It then becomes the duty of water pollution control agencies to determine whether or not the effluents meet accepted pollution standards. If industrial effluents do not meet established standards for discharge to waters of the State, the City of Cincinnati, Ohio, applies the same sewer charges as are applied to wastes going into public sewers.

If it is agreed that industrial wastes are to be discharged to public sewers, it then becomes fitting and proper to adopt rules and regulations governing the use of the public sewer system. "Manual of Practice No. 3"[2] of the Federation of Sewage and Industrial Wastes Associations states that every municipality should adopt a suitable and complete ordinance, fitted to local conditions, for the control and regulation of the use of public sewage works. It gives reasons for municipal sewer ordinances, details of ordinance composition, and a model ordinance. This model ordinance is of the so-called "long" type, which includes the detailed requirements for compliance. The manual gives very good coverage for a municipal sewer ordinance; many people would be satisfied with it for an industrial waste ordinance, because it does discuss industrial wastes in the section on "Regulation of Waters and Wastes Admissable to Public Sewers." The author, however, does not consider this model sewer ordinance as satisfactory for an industrial waste ordinance because there is no consideration of financing. The Industrial Wastes Committee of the California Sewage Works Association[3] went so far as to state that the whole matter, in the final analysis, is one of cost of disposing of troublesome industrial wastes and of who shall pay the price. It is unrealistic to ignore costs of handling industrial wastes when establishing industrial waste ordinances.

Establishing an industrial waste ordinance is no simple task. When one begins to consider all the different situations that may exist in different communities, it is realized that there is no single industrial waste ordinance, per se, for all conditions. The Industrial Wastes Committee of the California Sewage Works Association states[3] "no fixed policy can be set up for all cities to follow in connection with the treatment and disposal of industrial wastes. There are entirely too many factors involved in different cities to make one rule applicable to all."

Probably the best procedure is to first form a committee which includes those people best qualified to deal with the subject. It is important that both industry and municipal government, including the people required to administer the ordinance, be represented. Industrial waste ordinances have failed to pass in certain cities simply because governmental officials failed to take industry into their confidence. The committee can get all the facts, study them, evaluate them, and draw up an ordinance according to the best principles of practice. Various committees on a professional level in the fields of engineering, law, finance, and government have been giving this subject serious consideration in the last few years. The common exchange of ideas has been beneficial in establishing some basic fundamentals which should be studied and discussed by all those concerned with the subject.

The question of what should be included in an industrial waste ordinance is controversial. "Manual of Practice No. 3"[2] states that sewer ordinances used in municipalities of small and moderate size are usually self-contained in that they encompass all elements of control, including the detailed requirements for compliance. This is called a "long form" of ordinance. The Manual also states that in some large cities only a simple instrument is used, with the person or department administering the ordinance given the power to develop detailed rules and regulations, setting forth the specific requirements to be

met. The short form of ordinance is used by Detroit, the Boston Metropolitan District Commission, the Sanitary District of Chicago, and the Milwaukee Sewerage Commission.

The author prefers the short form of ordinance because of its greater flexibility and ease of application. Councils and Commissions are usually unfamiliar with the technical details of an industrial waste ordinance and consequently are reluctant to make any changes, regardless of need. When the professional person or persons administering the ordinance sees the need for changes in the rules and regulations which he or they have set up, it is a relatively simple procedure to make the desired changes or additions.

The Industrial Waste Ordinance of the City of Cincinnati, Ohio, for the Metropolitan Sewage Disposal System is a short form of ordinance, with provision for separate rules and regulations controlling discharge to public sewers. It was passed in 1953 to supplement the original sewage disposal ordinance of 1948 which was passed by City Council to provide funds for the Metropolitan Sewage Disposal System of Cincinnati; and to fix rates to be charged by the city to the owners of benefited property for the use of the sewer system and sewage pumping, treatment, and disposal works. When it was realized that the sewage service charge rates, on a volume basis, were inadequate to pay for the increased construction, operation and maintenance costs, two additional ordinances were passed in 1953. The Sewage Service Charge Ordinance modified the original ordinance by increasing rates on a volume basis. The Industrial Waste Ordinance supplemented the original ordinance by establishing rates of surcharge for wastes greater in strength, on a suspended solids and B.O.D. basis, than a defined "normal sewage" (300 ppm suspended solids and 240 ppm B.O.D.). The Rules and Regulations have been amended twice since their adoption in 1953 to remedy technical discrepancies.

Certain phases of industrial waste ordinances are fundamental, such as policy, legal requirements, financing and engineering requirements.

Policy

Policy should be established as quickly as possible because success is difficult without clear-cut plans. The initiative in establishing industrial waste ordinances usually falls on local government. If an industry is discharging its wastes to public waters, it will not be particularly interested in an industrial waste ordinance unless water pollution regulations are threatening its methods of waste disposal. If an industry is already discharging its wastes to public sewers, it will be reluctant to promote a program costing more money. Consequently, when local government is faced with the problems of water pollution regulations, it must initiate proper waste disposal methods, including considerations for industrial wastes.

If local government has a sewer system but no treatment facilities, it will sooner or later probably have to install proper treatment facilities. If it had no sewer ordinance previously to protect its sewer system, this need should become apparent when applying rules for discharge to protect treatment facilities. Moreover, it may need restricting regulations to meet effluent or stream standards.

The question of whether or not to accept industrial wastes into municipal waste disposal systems depends largely on local conditions. The relative volumes and strengths of domestic and industrial wastes vary considerably. The relative economic importance of an industry or industries in small communities often makes a big difference. It is generally agreed, however, that, except for accepted technical reasons, domestic and industrial wastes can be treated together in one system. If certain industrial wastes cannot be treated to the point of acceptance for treatment in the municipal system, they will have to be excluded.

If it is agreed that admissable industrial wastes will be handled in the municipal system, it is practical and realistic to provide for the cost of same in an industrial waste ordinance. The cost of handling industrial wastes will have to be met one way or another and it might as well be on an equitable basis. When industry and government work out the solution together, they can understand each other's problems and usually come to some common plan for financing.

The Cincinnati Industrial Waste Ordinance supplements the original sewage disposal ordinance, which established the sewer service charge to finance the sewage disposal program. It provides for a surcharge on industrial wastes which impose an unreasonable burden upon the sewage disposal system greater than average or "normal" sewage. It also prohibits any wastes which will damage the system or cannot be treated satisfactorily.

The Cincinnati Industrial Waste Ordinance was the result of many meetings with representatives of industry and public hearings. The Cincinnati Chamber of Commerce played an important part in bringing out the interests of everyone concerned. It is actually stated in the ordinance that the City of Cincinnati, in response to the request of industry, will build sewage treatment facilities capable of treating admissable industrial wastes in excess of "normal" sewage. It also states that industry has agreed to pay for those costs additional to treating "normal" sewage.

Legal Requirements

There are certain legal requirements for industrial waste ordinances. Laws vary from state to state and ordinance committees should seek legal advice to avoid mistakes which will hinder or even prevent the development and adoption of desired ordinances. All states have laws permitting political subdivisions to adopt ordinances complying with existing laws. Cities have had the greatest latitude over the years, but recently smaller communities and unincorporated areas have been given more administrative powers. More recently some states have passed laws providing for the incorporation of authorities for municipalities, counties, and townships.

Such authorities are authorized to acquire, construct, improve, maintain, and operate projects; to borrow money and issue bonds; to provide for the payment of such bonds; to establish rates for revenue, etc. Geographical or other special considerations may make desirable joint participation by adjoining municipalities or suburban areas. This may be achieved through the establishment of special districts for sewage purposes, covering an appropriate service area, or by functional consolidation.

For very practical reasons, procedures for establishing fair rates and rate structures should, so far as possible, be applicable to existing methods of financing under existing enabling acts or should point the way to statutory changes or innovations.

Charges for industrial wastes are usually based on sewage service charges or surcharges, and special financing agreements. Consequently, it is important to be familiar with all state financing laws and local regulations.

In most states, the issuance of general obligation bonds by local units of government is subject to limitations, sometimes constitutional, sometimes statutory, and usually expressed quantitatively by reference to assessed values of taxable property. Special assessment bonds are issued only where certain properties are recipi-

ents of special benefits not accruing to other properties. Special assessments may be levied by most municipalities and by municipal districts, commissions, and other types of local bodies, as may be authorized by statute.

Generally speaking, revenue bonds may be supported by a pledge of revenues received from operations in any legitimate area of operation, whether within or without the geographical limits of the borrowing unit. There is generally no legal limitation on the amounts of revenue bonds which may be issued; the limit is not legal, it is economic. Attention is called to the fact that the power to issue revenue bonds depends upon delegation by positive law. The courts of certain states have placed constitutional debt limitations on revenue bonds, holding that any particular issue of revenue bonds does not escape limitations unless they are to be paid solely from the revenue of the particular improvement. This is the "limited special fund theory," as opposed to the more generally accepted "broad special fund theory."

Many enabling acts prohibit the diversion of sewage income to other activities. The Pennsylvania law authorizing sewage charges requires that any surplus above a 10 per cent margin of safety be placed in the sewage sinking fund and forbids any transfer of funds to the general municipal funds. Unless the statutes prevent such a covenant, the municipality can agree to apply all surplus revenues not required for operation and maintenance, bond service, and the other funds provided for in the bond proceedings, to the redemption of its revenue bonds through call or purchase prior to their maturity as rapidly as surplus funds are available for that purpose. The Constitution of New York forbids the Legislature to prohibit municipalities from using profits from their public utilities for municipal purposes or for refunds to consumers.

Some state laws specify the purposes for which sewage charge revenues may be expended. New York and Ohio provide that revenues must be used first to operate, manage, and maintain sewers and treatment plants, and any surplus may be used for enlarging existing structures or for debt service. The statutes of both states specifically forbid the use of sewage charges for extending sewers into previously unsewered areas.

Financing

The Ohio River Committee[4] appointed by the Secretaries of War and the Treasury, according to the River and Harbor Act of August 26, 1937, reported in 1943 that the principal obstacle to the abatement of pollution is the actual financing of the necessary facilities. It is inevitable that people drawing up ordinances will be confronted with this problem. Some will say that it is the crux of the whole subject. So many plans have been proposed that there is little wonder that municipal officials and industries experience difficulty in approaching the problem. Too often fundamental considerations are lost sight of and expediency and the path of least resistance become deciding factors.

The most comprehensive report to date on fundamental considerations in rates and rate structures for sewage works is the Joint Report[5] of Committees of the American Society of Civil Engineers and the American Bar Association and representatives of six other organizations. The basic conclusion of this report is that both users and non-users should contribute to the needed total annual revenue approximately in proportion to the cost of providing for the use and for the benefits received. Schroepfer[6] has applied the Joint Committee recommendations to an illustrative example.

It is no simple task to apply the Joint Committee recommendations for fair sewage service charges. It is fundamentally one of first determining the total annual revenue requirements and distributing the costs in proportion to benefits and use. Costs for industrial wastes should be figured in with all other costs and then distributed accordingly.

Annual charges can be based on costs for (a) collection system; (b) intercepting sewers, including pumping stations; and (c) treatment facilities. The revenue requirements for these units are usually divided among (a) fixed charges or debt service, (b) operation, and (c) maintenance and replacement. After plans for the waste disposal system have been established, the first step would be to calculate the fixed charges for each unit of the system. It will be more difficult to estimate the operation and maintenance costs and they may have to be revised after operation data have been obtained. It will also be necessary to make allowance for such overhead costs as collection of revenue, field investigations, sampling and gaging of industrial wastes, laboratory analyses, administration, etc.

The allocation of costs is more difficult. Both property and the user are responsible for certain items of costs. It is reasonable to say that storm water, ground water, public use, and future use are chargeable to property. The charges to users are based on the characteristics of wastes discharged to the system. The relative proportions of costs to property and users will vary in the different units of the system. The size and cost of collecting sewers and intercepting sewers are caused wholly by the quantity of sewage. The percentages for pumping stations are based mainly on quantities with due regard for that part of the cost of screens and screening disposal facilities caused by use and by storm water; and to the wearing of pump parts by grit in storm water.

In the treatment plant, the percentages caused by use and by property depend on both the quantity and the characteristics of the sewage. A study of the costs of various parts of each major part or function is required. Thus, the cost of screens and grit tanks is attributable mainly to grit and storm water from property. Sedimentation costs are affected principally by volume and chargeable to both property and users. On the other hand, the costs of secondary treatment and sludge disposal processes are caused largely by users.

After costs have been allocated, rates and rate structures can be established. Property costs are usually paid by general property taxes, although front footage or area rates may be used. Since costs to users are based on both volume and strength of wastes, it is reasonable to base revenue rates on these same indices. Many municipalities have revenue rates based on volumes, but very few apply rates based on strengths of wastes. It is a relatively simple matter to apply volume rates because the water departments have water consumption records and private wells can be metered. It is impractical, however, to try to determine the strengths of all wastes. It is more practical to establish a service charge based on volumes of a so-called "normal" sewage and then apply a surcharge on all stronger wastes. Surcharge rates should be clearly defined. They may be expressed by formulas, but it is simpler to use rates per pound of each chargeable constituent.

In relatively small communities, agreements are often made with industries to pay for industrial waste disposal costs. Payments may be in the form of lump sums, fixed annual amounts, or compensation on a percentage basis.

The important thing to remember is that there is a definite cost for handling industrial wastes. This cost must be paid for and those parties responsible for financing should make every effort to work out equitable charges.

Cincinnati employs a combined method of financing sewage disposal facilities. Collection sewers are financed by general obligation bonds, whereas street sewers are paid for by special assessments on a lineal foot basis. The intercepting sewers, pumping stations, and treatment plants are financed by mortgage revenue bonds, revenue for which is obtained from both a service charge on normal sewage and a surcharge on wastes greater in strength than normal sewage. Both the service charge and the surcharge rates are subject to review at least every five years.

Rates are the same to all users in the Metropolitan District regardless of whether or not they are in the city limits of Cincinnati. Charges for industrial wastes were determined by the incremental method. The additional cost for handling wastes stronger than normal sewage were calculated. Then the annual charge for industrial wastes was estimated and a formula developed to produce the necessary revenue.

In connection with revenue charges, it might be well to point out a method employed by Cincinnati to encourage cooperation of industry. Provision was made in the industrial waste ordinance for agreements between the city and industries, whereby the industries could obtain refunds if they signed agreements within six months after the effective date of the ordinance to install pretreatment facilities within twelve months after the collection of the sewerage surcharge became effective. The refunds were based on reductions of strengths of wastes, and applied to wastes discharged to both the public sewers and public waters. These special sections were actually bonus clauses to industry for initiating waste treatment facilities.

Engineering and Technical Requirements

There are many engineering and technical questions to be answered before an industrial waste ordinance can be established. Even though such an ordinance is concerned primarily with industrial wastes, it is necessary to have certain data on the whole sewage disposal system. Not only must the characteristics of the industrial wastes be known, individually and collectively, but also the characteristics of all the other sewage discharged to a common treatment plant or plants. Having determined the characteristics of total wastes to be treated, it is necessary to determine the degree of treatment to meet effluent or stream standards.

After total costs of construction, operation, and maintenance have been estimated, rate schedules must be calculated to meet revenue requirements for the industrial wastes. In addition, it will be necessary to make technical decisions regarding admissability of wastes to public sewage disposal systems. Many municipalities retain consulting engineers to work out all the engineering problems; others retain them to work with their staffs. In any event, it is always practical to have experienced engineers review the technical plans.

Engineering studies must include not only investigations of present wastes but also reasonable predictions of future ones. Topographical surveys should be made to determine future trends of industrial and residential growth and properly locate intercepting sewers. It will be necessary to gage and sample the sewage at representative points in the collection system in order to determine the characteristics of the wastes discharged to treatment facilities. Pollution surveys should be made on the receiving stream before the degree of treatment is determined. The question of having more than one treatment plant must be answered, as well as the types of treatment units. The choice of plant location may require considerable study.

Rules for prohibiting certain wastes from the disposal system should be established at the time the ordinance is presented for approval, so that all parties concerned will understand the conditions. Certain wastes should be prohibited for four reasons:

1. To protect the collection system.
2. To protect the treatment plant.
3. To meet effluent or stream standards.
4. To protect personnel.

The prohibitions may apply to the wastes at their source, after they reach the plant, or as they discharge from the plant. For example: acid wastes should not be discharged to sewers because of their destructive action on the materials of construction; excessive quantities of certain metal salts should not be admitted to treatment plants because of their toxic action on treatment processes; and excessive quantities of soluble fluorides should not be discharged from treatment plants because of their effect on downstream public water supplies.

Considerable thought should be given to the rules for admission of industrial wastes to sewage disposal systems. It is not wise to adopt certain rules simply because they are in some other ordinance. Too often these rules are simply hand-me-downs and may be out of date or non-factual. When they are placed in the ordinance proper, they are usually expressed in general terms. When they are placed in the rules and regulations, outside of the ordinance, they can be spelled out with specific numerical values. Industry always wants to know the exact conditions of compliance.

Requirements For Industrial Waste Ordinances

The question of whether or not industrial wastes discharged to municipal sewage disposal systems should be controlled by a general sewer ordinance or a separate industrial waste ordinance is a matter of opinion. If an existing sewer ordinance does not fully cover industrial wastes, it might be more practical to develop a separate industrial waste ordinance. It would be well to review all existing regulations, such as building codes, plumbing codes, and health regulations. These can be incorporated in the industrial waste ordinance or its rules and regulations, or they can be noted by reference. Many of the rules for use of public sewers in Cincinnati's Industrial Waste Ordinance have been in the City Building Code for years.

The question of whether or not an ordinance controlling discharge of industrial wastes to a public sewage disposal system should be of the short or long form is also a matter of opinion. Reasons have already been stated for believing that a short form with separate rules and regulations has advantages over a long form. Reasons also have been given in favor of provisions, right in the ordinance, for collecting revenue.

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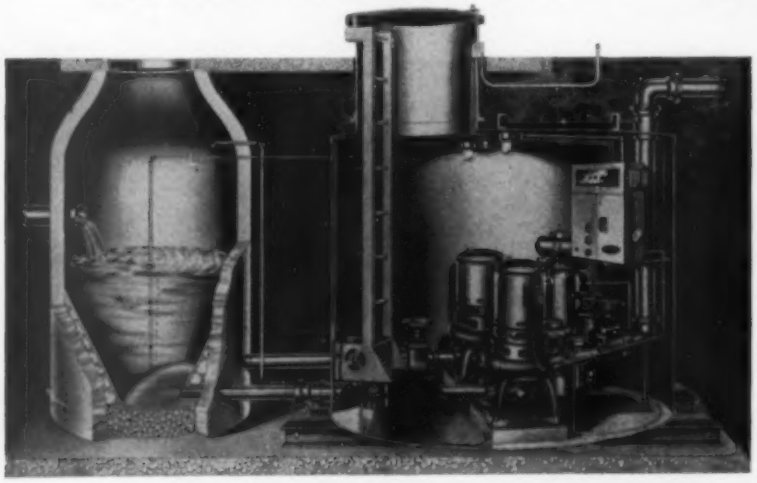

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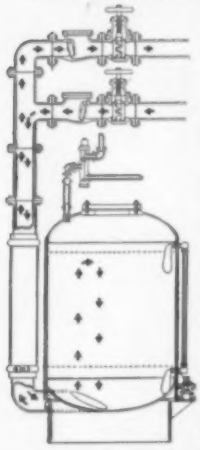

Ideal for installations such as sub-divisions, lift stations, or sewage treatment plants requiring capacities of 200 G. P. M. or less. Since sewage does not come into contact with any part of the control system, the "WAY-O-MATIC" design practically eliminates maintenance.

The "WAY-O-MATIC" may be ordered as a separate unit or in a complete duplex lift station. Cutaway drawing shows operating cycle.

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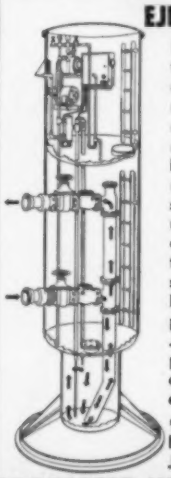

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Cutaway drawing shows how the "MON-O-JECT" operates.

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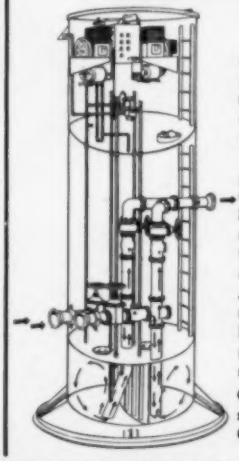

Most small sewage lift projects are served most economically and dependably by a Smith & Loveless "MON-O-JECT" single pneumatic sewage ejector lift station. If duplex equipment must be provided throughout, the Smith & Loveless "DU-O-JECT" duplex pneumatic sewage ejector lift station meets the requirement most economically.

Cutaway drawing shows how the "DU-O-JECT" operates.

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Sewage Pumping Station Design Principles*

by RAYMOND G. MARTIN

Civil Engineering Associate, City of Los Angeles, Los Angeles, Calif.

IN ALMOST every new sewer system or expansion of an existing system, it is necessary to provide means of lifting the sewage at some point. In areas where the topography is flat or contains depressions, it is often less expensive to provide pumping facilities than to construct gravity sewers in deep excavations or through tunnels.

Expansion of urban areas beyond existing sewer facilities often necessitates the use of pumping stations to discharge sewage into existing sewers or treatment plants. It is sometimes necessary when sewage treatment plants are constructed in areas having a relatively flat topography to pump the sewage at the treatment plant site to obtain gravity flow through the plant. Regardless of the reason for their use pumping stations are less desirable than gravity flow. Every pumping station has maintenance and operational problems. Operating personnel and power are continuing cost items. Therefore, a sewage pumping station should never be constructed where a safe, economical substitute will suffice.

Types of Pumping Stations

A sewage pumping station is a collection of equipment and materials assembled for but one purpose—to pump sewage.

There are many types of pumping stations in existence today which may be classified as follows:

1. Wet pit pumping stations consist of a sump or wet well with the pump or pumps submerged in the sewage. In this type station the pump, shaft and supporting facilities are exposed to the sewage. The motor is usually located at an elevation above the pump and in most cases is exposed to an atmosphere of sewage gases. The difference in elevation of the pump and the motor requires a long shaft, which frequently is a source of trouble. The present trend is to avoid wet pit type construction.

2. Pneumatic ejector pumping stations may be used to great advantage for small installations. An ejector consists of a large pot which receives the sewage and expels it by means of compressed air. Despite their low efficiency (15 per cent) ejectors are desirable for small installations because little maintenance is required.

3. Dry well pumping stations are the most generally used type. The pumps, motors and all appurtenant equipment are isolated from the sewage and located in a dry, clean area. Dry well pumping may be practiced using: (a) constant speed pumps, provided there is storage to take care of the variations in flow; (b) variable speed pumps with little or no storage.

The second method is relatively new and is not widely used at the present time. Where constant speed pumps are used approximately one-half of the station structure is designed for the storage of sewage. This portion of the station requires hard and dirty work to keep it clean and functioning properly. As a result maintenance personnel may neglect this work, which frequently causes operating trouble.

In comparing the two methods of dry well construction, it is apparent that capital costs are much greater for construction of the storage type structure. This is not only true because of the area requirement, but more so because of the additional depth required for storage. In either case, the receiving facilities are equal for equal flow. Reduction of the storage areas required does not eliminate all maintenance; however, it does reduce the quantity and some of the objectionable portions of the maintenance work.

It is not the scope of this paper to discuss all the design characteristics of a sewage pumping station. A few general features and procedures are included and some design problems are discussed in detail. However, it is a responsibility of the design engineer to consider in detail every feature, piece of equipment and operation of the entire pumping station. This includes everything from the dynamics of the pump impeller to the color of the paint on the walls.

* Reprinted from *Sew. & Ind. Wastes*, Vol. 28, No. 2, p. 150 (1956)

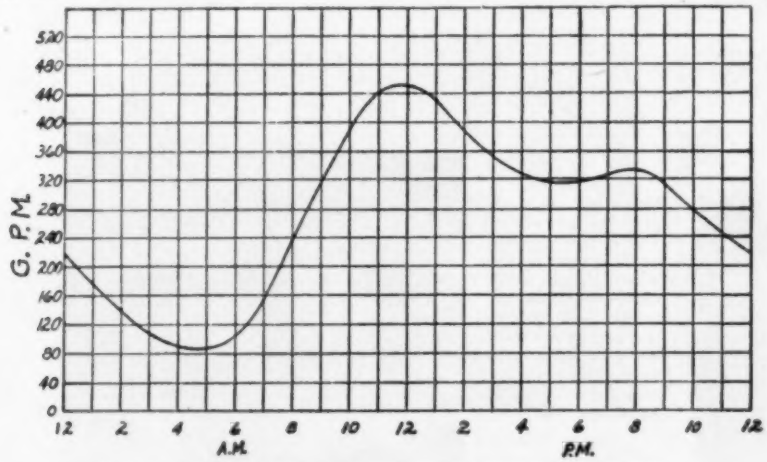

FIG. 1.—TYPICAL flow duration curve for sanitary sewage.

Design Considerations

The first phase of pumping station design is to make a preliminary investigation to determine if a pumping station is necessary. Many troublesome pumping facilities could have been eliminated if their necessity had been kept in mind. Economics is not the only consideration relative to feasibility of design. There are many intangibles connected with pumping stations which must also be considered.

Location

Location of the pumping station is relatively simple in new developments, but in the expansion and remodeling of an existing system it may require extensive study. Both the anticipated and existing flow must be determined, since frequently the failure of a station can be traced to an incorrect analysis of the flow. Proximity to residences and possible odor and noise nuisances must also be considered.

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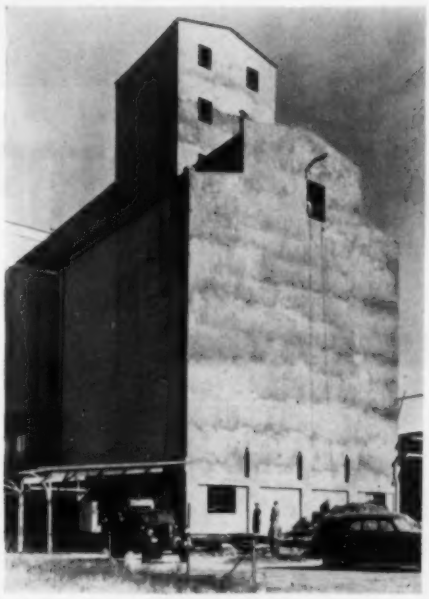

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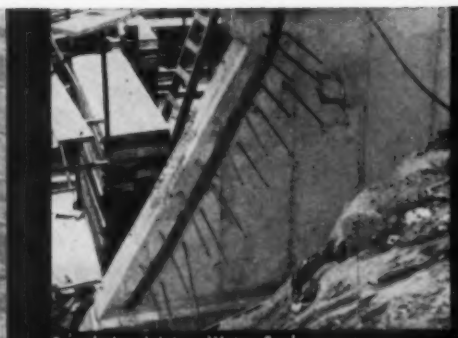

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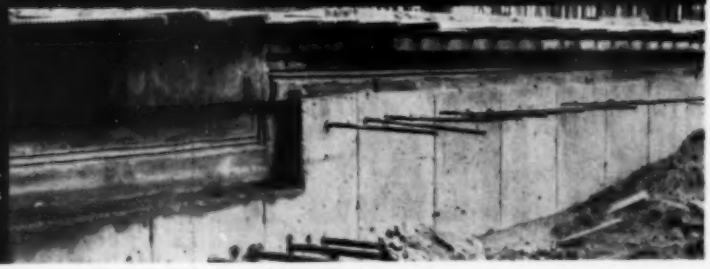

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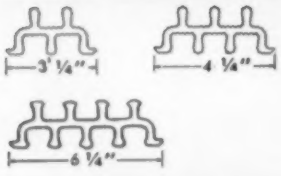

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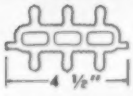

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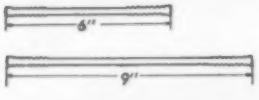

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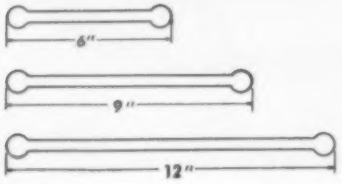

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Finally the type of pumping station must be determined. Here, the engineer's background and ability are most important. Consideration must be given to a number of factors including: (a) the qualifications of the available maintenance personnel; (b) the sewer system as a whole; and (c) the type and quality of sewage to be handled.

Flow

In studying the flow there are two primary characteristics to be considered: (a) the flow duration curve (Fig. 1) or the rate of flow relative to time of day, and (b) the accumulated quantity of sewage relative to time. The rate of flow serves as a basis to size the proposed pumping station when variable speed pumps are to be used. In this case the pumps must be capable of handling both the low and high flow with proper consideration for weekly, seasonal and future variations. Sizing of receiving facilities is also based on this information.

The mass diagram curve (Fig. 2) which shows the accumulated quantity of flow relative to the time is used to size pumps, receiving facilities and storage required where fixed speed pumps are to be used. Predicted flows, as well as the present flow, should be included on the mass diagram. This is essential because the required storage capacity as based on this information will be permanent, and in most cases cannot be increased economically at a later date.

In the theory of the mass diagram the ordinate represents the accumulated quantity and the slope of the curve is the rate of flow. Pump curves can be plotted with slopes corresponding to capacities of the pumps and storage facilities are plotted as fixed ordinates. By adjusting these to the mass curve, the capacities of the pump, receiving facilities and storage reservoir can be determined for any desired time. This analysis presents a picture of the pump cycles of the pumping station operation. For small flows the mass diagram principle also may be applied to variable speed pump design. However, in large rated flow pumping stations the storage element is negligible, making this method impractical.

Sizing of Pumps

There are two methods of preparing plans and specifications for pumps. The first is to ask a pump manufacturer to furnish a pump for the installation. The second is to develop the design and to specify the conditions to be met by the pump. The first method eliminates competition and may have an adverse effect on the quality of equipment procured. This does not mean that the design could not be developed around a particular pump. Quality and performance, should be the basis for selection rather than brand name. Close cooperation between the pump manufacturers and the engineer is essential for good design.

Pump Characteristics

Figure 3 is a typical pump analysis for operation only, showing the system curves and the pump characteristics curve. This particular analysis was not for a new installation but for an expansion of an existing facility. This pumping station was operating at a maximum capacity of 32 c.f.s. and it was necessary to provide for an increase in capacity. The total head on the pumps was 90 ft. This particular curve shows four different system curves and one force main curve. The upper system curves represent the total loss in the system and are equal to the sum of the piping losses and the force main loss. The four different curves represent four possible operations, such as 1, 2, 3 or 4 pumps operating together. This is known as compounding pumps in parallel. The wide separation between the force main friction curve and the total system curve indicates a considerable length of pump manifold. While this is not desirable, there was no way of eliminating this condition.

Also shown are four pump curves which represent any combination of the four pumps compounded in parallel. The point of intersection of the pump curve and the system curve is the point at which the pumping station would operate if all other conditions remained equal. However, in actual practice this is not true. The system curve varies with a change in friction coefficient as well as changes in the water level of the wet well. Therefore, operation can be predicted within a range but not to a point. In almost all cases it is advisable to analyze the pumps for maximum and net average static head.

The design points for the particular pumps being studied are at 10,000 g.p.m. and 6,000 g.p.m. In the lower

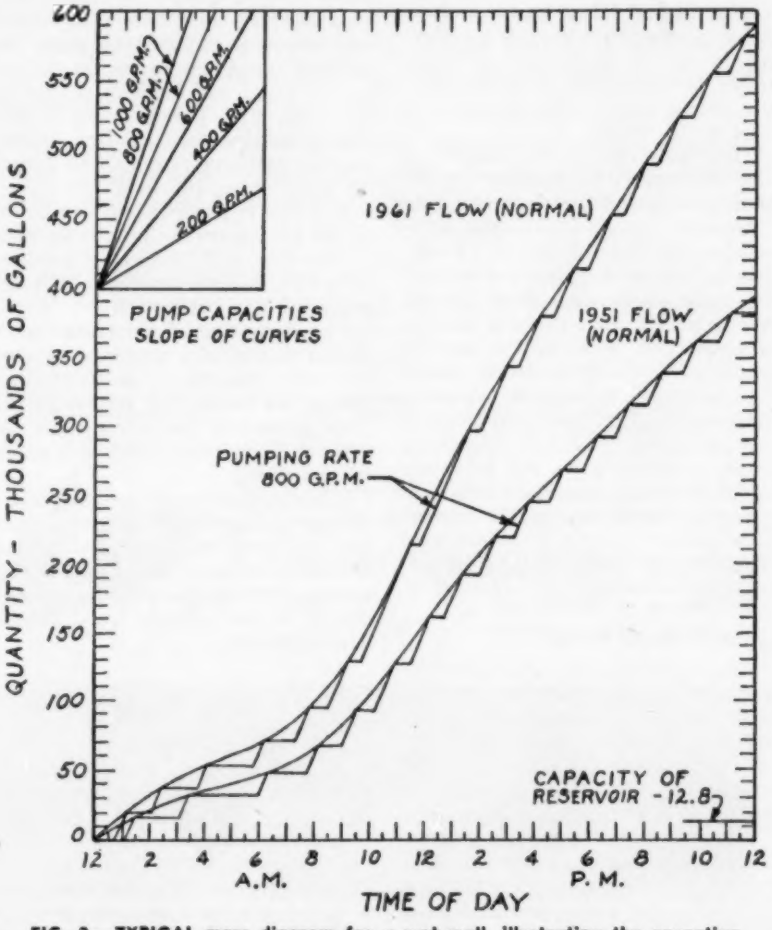

FIG. 2.—TYPICAL mass diagram for a wet well, illustrating the operation of the pumps.

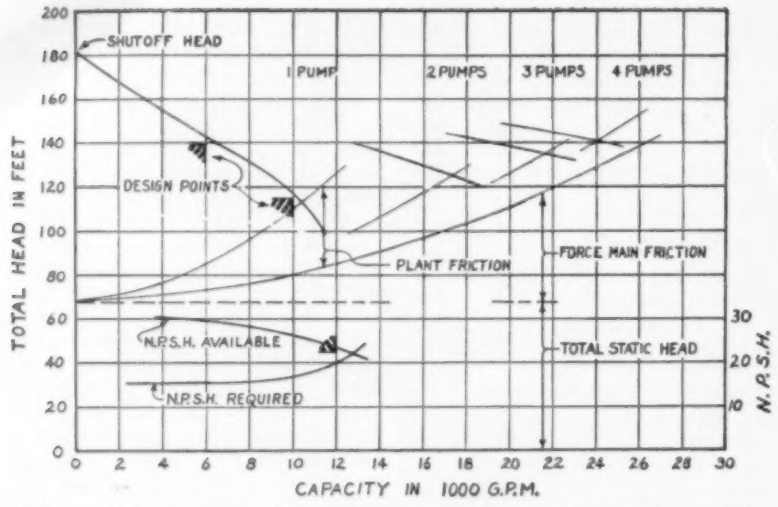

FIG. 3.—TYPICAL pump analysis curves showing the system and characteristic curves.

left hand corner are shown two curves labeled N.P.S.H. Available and N.P.S.H. Required. The term N.P.S.H. denotes the net positive suction head and is defined as the gage reading in feet taken on the suction nozzle as referred to the pump centerline, minus the gage vapor pressure in feet corresponding to the temperature of the liquid, plus the velocity head at this point.

The "Required" curve was plotted from the factory information for the particular pump furnished. The "Available" curve is normally computed at the time of design. In considering the section characteristics of the pump at the time of design the Available N.P.S.H. curve is studied in connection with suction specific speeds and critical cavitation sigma. By comparing the critical cavitation sigma and suction specific speed with the computed N.P.S.H. Available curve, a design point can be established for the Required N.P.S.H. of a pump. As shown by the curves, these pumps operate at a minimum N.P.S.H. Available of 22.5 ft. and require a minimum N.P.S.H. of 20 ft.

Constant Speed Pumps

The specifications developed for this particular pump relate to characteristics only. The characteristics of the pump shall provide 10,000 g.p.m. at 115 ft total dynamic head and 6,000 g.p.m. at 140 ft. Variation in head shall not exceed +2 per cent or —4 per cent. Maximum brake horsepower shall not exceed 400 at capacities from 0 to 12,000 g.p.m. Required N.P.S.H. shall not exceed 22.5 ft. at 12,000 g.p.m. and the pump shall not cavitate under this condition.

Variable Speed Pumps

The design is somewhat different when variable speed pumps are used. Figure 4 shows the analysis of a two-pump variable speed installation. The head capacity curves are plotted for various speeds of pump operation. In addition, the system curves are shown for one pump and for both pumps in operation. The system curve is not continuous because the first pump must be operating at full speed before the second pump cuts in. When a horizontal line is plotted from any point on the system curve the intersections of this line with the characteristics curves indicate the operation of each pump for a given capacity.

The derivation of these curves is similar to that of a conventional system except that there is no direct solution to the secondary system curve. This portion of the curve must be derived by means of trial and error computations.

While variable speed pumping is becoming quite common for rated flow type pumping, variable speed pumps are not often used in multiples. The present trend in pumping station design is to use variable speed pumps where possible.

Pump Types

Although there are many makes, types and designs of pumps available anly a few are satisfactory for pumping sewage. Each pump has been designed for a specific purpose within limiting conditions and to use a pump for any situation for which it was not designed is certain to cause trouble.

Where variable speed design is used the following methods have proven satisfactory for obtaining the desired results:

1. Wound rotor motors.
2. Hydraulic couplings.
3. Variable pitch pullies with belt drives.
4. Magnetic couplings.

Each of these methods gives approximately the same results, although the first method cannot be changed at a later date. Another relatively new method uses a pump with a built-in bypass for the return of excess flow.

The pumps are one of the most important parts of a pumping station. Therefore, it is not unreasonable to spend considerable time and effort in designing and specifying the equipment.

Pump Installation

Sewage pumps in a dry well type pumping station may be installed by one of the following methods:

1. Pumps with isolated motors.
2. Pedestal mounted pumps.
3. Close coupled pumps.
4. Horizontal pumps.

Methods 1, 2, and 4 may be used for installations of variable speed pumps.

The use of isolated motors is the oldest method and is still the most common. The motor is isolated by placing it above the highest possible flooding level, which is usually at the ground line. The pump is then connected to the motor with a long shaft which, when not installed perfectly, is a constant source of trouble and expense. During recent years the trend has been to eliminate this long shaft. Experience indicates that flooding of the pump pit is not caused by storms, accidents and power failures, but by poor design and maintenance. With proper design, isolated motors are not essential for reliable operation.

The use of horizontal pumps is considered best for ease of maintenance and installation. However, larger floor areas are required in the pump room and this adds to the capital cost of the pumping station.

To complete the design of the dry well portion of the pumping station provision must be made for all supplementary equipment necessary to proper operation and maintenance of the station. This equipment may be classified according to the following groups:

1. The piping system includes valves and supports, taps for gages, drains and flexible couplings. Substantial bases and flexible couplings should be provided to prevent transmission of pump vibrations. Flexible rubber fittings are now available

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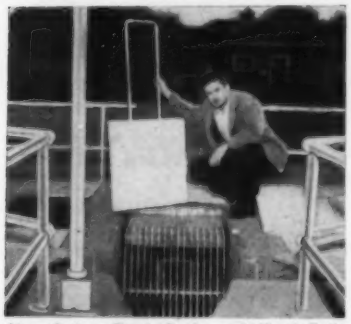

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which have sufficient strength and life to be satisfactory for sewage pumping.

2. A priming system for the pumps is essential where continuous automatic operation is intended. This may be accomplished conveniently without the use of special priming equipment if proper consideration is given to operation and arrangement of equipment. Interconnecting the pumps in priming and air release systems must be avoided.

3. Access to the equipment should be given careful consideration since it is customary for an operator to service the station alone. All hazards should be removed by design and not by experience. Hatches and doors must be sized for the removal of all equipment and hoisting equipment provided for the handling of heavy or massive equipment.

Pump Controls

Where automatic operation is proposed the heart of the pumping station is the controls. If the controls fail to respond to flow or liquid level changes the entire station fails. Among the many types of controls presently available are the electrodes, the floats, the air bubbling systems, the electronic and radar systems, and the flow meters.

All controls require some maintenance for continuous satisfactory operation. Normal sewage contains solids, grease and rags, which cause clogging, shorting and fouling of the controls. To keep the controls in operation it is necessary to clean them frequently and in some locations this may be as often as twice a day. Cleaning and servicing controls is a dirty and expensive job. Therefore, every consideration should be given to the design and selection of controls in an effort to eliminate cleaning costs.

The electrical system of a pumping station is similar to that of any industrial installation, except that portions of a pumping station are often subjected to hazardous conditions caused by the sewage atmosphere. In some locations this requires the use of explosion proof fixtures.

Receiving Facilities

The receiving portion of a pumping station consists of a structure and equipment to receive, control, screen and store the sewage. In a rated flow type pumping station little or no storage is provided. With this one exception, the required receiving facilities are the same for either type of dry well construction.

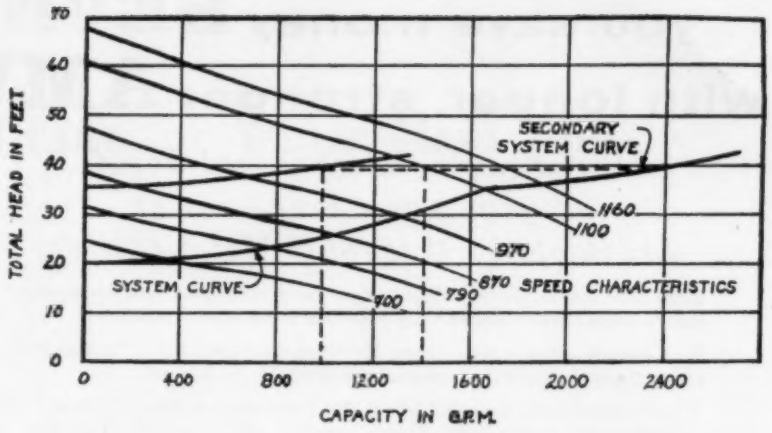

FIG. 4.—TYPICAL analysis of a two-pump variable speed installation.

The pumping station, depending on size, should be provided with a control gate, sand trap, diversion gates, bar screen and either a grinder or a comminutor. In addition, pump suction connections, stilling basin and hose bibbs for cleaning should be incorporated in the design.

The inlet sewer should always be provided with a gate valve or sluice gate to stop the flow of sewage for reasons of maintenance and emergency. Frequently this control is located in a manhole near the pumping station. When possible the inlet sewer should be provided with an overflow or emergency bypass.

When the pumping station is of sufficient size the inclusion of a sand trap may be warranted. Normally a 6-in. to 8-in. depression in the influent channel is sufficient. This prevents the accumulation of sand in the wet well where it is difficult to remove.

Bar screens are necessary regardless of the use of automatic grinders. Provisions must be made for cleaning these screens and removing the screenings from the station. When an automatic grinder is provided the inlet channel is split following the sand trap to provide for both the grinder and a bar screen. Experience shows that grease is now beginning to cause trouble with grinders. Manufacturers of this equipment should be consulted concerning the particluar feature of their units.

Sewage from the bar screen and grinder should not discharge so that it causes violent turbulance in the storage area. This turbulance is undesirable since it causes the liberation of dissolved gases from the sewage, particularly hydrogen sulfide.

The stilling basin or storage reservoir is where the sewage is stored for constant speed pumping and where it is allowed to become quiescent before pumping in a rated flow pumping station. It is also in this area that the pump controls are located.

Ventilation is essential before any person can enter an active wet well. In many installations ventilation is a constant problem. If the wet well is not ventilated it is unsafe for operators to enter; if it is ventilated local residents complain of odor nuisance. Recent tests made by the city of Los Angeles, Calif. indicate that a 5 min. air change is both sufficient and desirable, provided the atmosphere entering through the inlet sewer is included in the quantity to be exhausted.

Other Considerations

Once the capacity and characteristics of the pumps have been determined, all other hydraulic features of the station can be designed. The force main is designed as a pressure pipe based on pump capacity. Air pockets either should be avoided or provision made for the release of air or trapped gases.

The appearance of the above ground pumping station structure and the landscaping of the grounds should not be neglected. Structures and landscaping that blend with the contemporary features of the surrounding area are essential if the pumping station is to be accepted in the neighborhood. For large pumping facilities provision should be made for operating personnel and visitors.

Pumping stations are normally designed for a life of 40 to 50 years. With good engineering design they should satisfactorily serve for this period.

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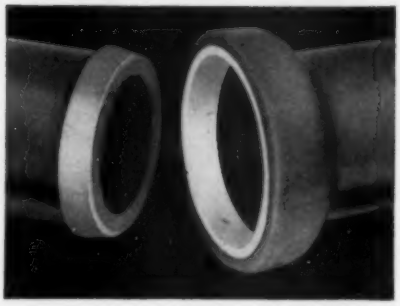

More than 200 major installations have been completed with outstanding results since Amvit Jointed Clay Pipe was introduced in 1955.

Such pioneer cities as Ann Arbor, Michigan, Dayton, Ohio, Camden, New Jersey have installed their second and third Amvit sanitary lines.

A mechanical joint designed for quick, low-cost installation, Amvit* will give you lower cost-in-place. Here's how:

1. QUICK INSTALLATION SAVES LABOR

No other materials such as caulking, joint compound, hot pots, or ladles are needed to make the Amvit joint. The joint is on the pipe delivered to the job ready for use. Just push the pipe together and the joint is complete.

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You can backfill as soon as the line is completed. Barricades can be removed and streets opened days sooner.

3. QUICK TESTING

No need to wait days to see if a line has passed test. A look at the completed joint will tell. Thus, engineers can inspect and accept the line allowing the contractor to receive payment quicker.

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Amvit is a compression joint on the ball and socket principle. The surfaces of both bell and spigot are in uniform compression preventing root penetration.

6. BETTER FLOW, LESS MAINTENANCE

The design of the joint assures that the pipe is self-centered at all times. This gives perfect alignment and self-cleansing. Because the joint is really tight, no foreign matter such as dirt, sand and stones can possibly enter the line.

7. COMPLETE FITTINGS

Amvit is furnished on all standard fittings, as well as pipe. This will permit a uniformly tight line from house wall to treatment plant.

Amvit Jointed Clay Pipe, in sizes 4" through 24" together with all fittings is available for immediate delivery in the Northeast and Central States.

For more information on how Amvit can help cut your sewer project costs, write or call American Vitrified Products Company, National City Bank Building, Cleveland, Ohio, or our office nearest you.

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Transit Crane for Water Main Jobs

by DANIEL J. CONLON
Bucyrus-Erie Company, South Milwaukee, Wis.

GROWING pains are common to many American Communities—young and old alike—in a rapidly expanding industrial age. As a small village or town grows in population and area, public officials are confronted with the difficult problems of providing additional utilities, building new roads, etc.

Among such blooming villages is the Town of Tonawanda, just a few miles north of Buffalo, N. Y. It lies at the easternmost juncture of the Tonawanda Channel which, with the Chippewa Channel on the west, splits the Niagara River to circumvent Grand Island before spilling over famous Niagara Falls.

Not the least among the town's present problems is that of meeting water demands of both domestic and industrial users.

The Town of Tonawanda is an industrial center whose residential areas have mushroomed due to a heavy influx of skilled laborers. As a forward step in solution of one of their city's expansion problems, officials have undertaken an extensive program which includes building of a new intake into the Niagara River, a new pumping station, and a new water treatment plant.

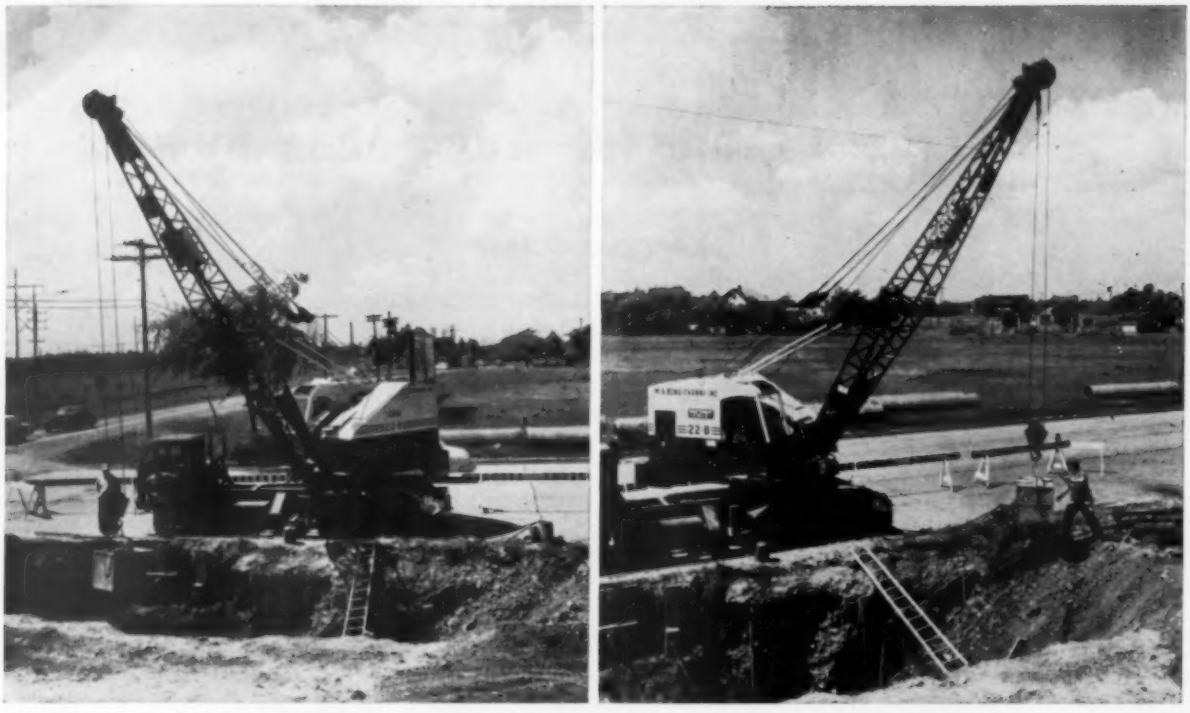
In conjunction with additions to the water supply system, a new transmission main was required. The $830,000 contract to put in a 6.25-mile long feeder main pipeline system from the treatment plant to city users was let to M. A. Bongiovanni, Inc., General Contractor, of Syracuse, N. Y.

The contract covered a route in a northeasterly direction, much of it along busy Sheridan Drive in suburban Buffalo. A major portion of the work involved ordinary trenching. However, state legislation—affecting a portion of the work—made this a tough assignment. Tunnel work was required under all railroad crossings and county and state highways where open cutting is restricted by law. The new transmission main crosses 15 to 20 such intersections, and 900 lineal feet of underground boring was necessary. All intersections were kept open during boring operations.

Tunnel Work

The first and longest of the tunnels required on this contract was located at the Kenmore Avenue - Sheridan Drive intersection. Railroad tracks, running parallel to Kenmore, necessitated a tunnel drive of 104 feet. Casing here consisted of three sections—

Traffic flows freely along intersection near Tonawanda, N. Y. as truck crane cleans out around tunnel borer



INEXPENSIVE 1-yd bucket was filled and dumped by hand because loose clay being removed was usually in areas inaccessible to clamshell bucket. Note adjustable steel braces for 12-ft deep pit providing working space for horizontal auger

two 40-ft and one 24-ft weld-jointed units. The casing was 48-in. OD x 3/16-in. wall steel. Both 30-in. diameter Lockjoint prestressed concrete cylinder pipe and 20-in. diameter mechanical joint cast-iron pipe were used.

For this type of work, a Ka-Mo horizontal earth auger, powered by a 53-hp International gas engine, was used to bore out the tunnel and at the same time drive the casing under the intersection. Two 12 x 12-in. x 24-ft long timbers, bridging the boring pit at the head end of the tunnel, acted as a deadman for winches which pulled the casing into the bank.

The boring machinery was based in a wide trench about 12 feet deep, the base of the tunnel being about the same depth under the road. This method was followed on each of the intersections. However, the standard trench along 95 per cent of the line was only 6 feet in depth. Most of the trenching was assigned to one of Bongiovanni's dragshovels.

Trenching

Excavation figures are not available. Superintendent John C. Taggart, in describing the activity, explained that yardage is relatively unimportant in this type of work as most of the dirt was put back on the pipeline. The material was mostly clay with occasional boulders.

Although trenching was handled by conventional hoe equipment, a variety of work around the boring operation, plus maintenance assignments along the line, were handled by a new Bucyrus-Erie 22-B Transit Crane, a 25-ton carrier-mounted lifting crane.

The mobile crane was used wherever the need arose, including rearranging pipe, setting in valves and pipe, and cleanup work around valves and pipes from one end of the line to the other. It also was used to clean up around the boring machine, where it occasionally was necessary to free the casing of loose clay deposited from the cuttings and from minor slides along the trench wall.

For this latter work the crane was fitted with a 1-cu yd tilt-bucket, which was lowered into the hole, filled by hand shovel with clay from inaccessible areas under the casing, then raised and dumped to the rear of the trench. Excavation of the work area also was handled by the Transit Crane, equipped with ¾-yd clamshell.

In addition, the crane was used as a supporting and leveling device for the auger. After lowering the 5-ton boring machinery into the trench it assisted in keeping the auger level to prevent sliding up, down, or sideways, and to minimize binding along the trench floor, which was spot lined with 12 x 12-in. timbers.

For this work, the crane was equipped with a standard short boom, 30-ft long without inserts. This was advantageous in short, heavy lifts and for working near intersections where low overhead wires, etc., were frequent problems. A boom angle indicator, located on the boom, varied from 30 to 60 degrees through most of this job.

The crane operator is George A. Chaffee who has had 44 years of experience on cranes and draglines.

Cutting Large Diameter Cast-Iron Pipe

by J. P. HENNINGS
Superintendent of the Portland Water District, Portland, Me.

ONLY THE OTHER DAY, with pipe to cut—too much pipe to cut—a foreman reported that our pipe cutting machines were both busy. The suggested solution was to cut it with diamond points—as of "yesterday."

Only a very few years ago this situation could not have existed; the cutting would have been done by diamond point and no questions asked. Subsequent to that period was the era during which the foreman's cry was "We don't want that new fangled machine, we can do the job quicker with diamond points." The other day, just with the suggestion of "diamond pointing" the reaction was quick and emphatic: "That's a lot of work! It'll take all day!"

The cutting of large-diameter cast-iron pipe has, until recently, been one of the most unsatisfactory operations in the construction and repair of water mains. Here in Portland, considerable thought and a good deal of money has been spent in recent years with a view to improving this situation. We have now arrived at the point where nearly all cuts, both in the ditch and on top of the ground, are made with pipe cutting machines. We feel it is far safer than either cold cutters or use of the "diamond-point-and-bust-out-with-a-sledge" method. Time consumed is short, and when you get done you have cast-iron pipe left, not scrap iron.

On the smaller sizes (2 in. through 12 in.) either knife-type ratchet cutters or wheel-type cutters are used, with more of the knife-type being used on the 8 in. to 12 in. pipe. On the 2 in. cast-iron pipe cutting is done with a regular three-wheel cutter. But when it comes to cutting the larger sizes of pipe we really go overboard. We bought a pipe cutting machine a couple of years ago and found that it cuts pipe above ground or underground or almost anywhere you can find about 18 inches clear along the pipe and you can get about 18 inches of hole around the pipe. The one machine cuts all sizes from 10 in. to 48 in., inclusive.

Of course, it is understandable that we didn't just up and buy this machine without considerable meditation and soul-searching, not to mention more practical considerations (such as justifying the expenditure to the Trustees of the District) after demonstrations had indicated the desirability of ownership of the machine.

It came about this way: we had quite a number of cuts to make in connecting the new Sebago Lake intake into the existing system. Space and time were limited. Shut-downs could be made only on Saturday nights, so 30 in. and 42 in. fittings had to be done literally "overnight." Both limited space and time seemed to make hand cutting impossible.

We heard of a machine that would cut pipe at the rate of one minute per inch of diameter, but we didn't have a machine and we weren't sure enough that it would do all that was claimed for it to venture the seemingly high investment. Water works men all know how it is. Often you have to

TYPICAL pipe cutting jobs with the new cutting machine

make a shutoff and do a job, although you can't be 100 per cent certain as to how long it will take or just how it will go together. You just hope and pray it will. We all worry about ordinary shut-downs. But when we had to shut down the only supply line to a community of 150,000, without being sure as to the success of the cutting method, or of the time necessary for the work, we nearly had nervous prostration worrying about it. And, frankly, we didn't take too much stock in this one-minute-per-inch-diameter cutting rate which was claimed.

So, We Just Rented A Machine

Imagine cutting 42 in. pipe in 42 minutes! But we had to go ahead—and hope. So, we arranged to rent a machine at the rate of one dollar per inch of cut. We found that it did not cut 42 in. pipe in as short a time as 42 minutes—it took almost 45 minutes! With the rented machine we got the cuts made and the new connections finished in plenty of time.

We had made several 42 in. cuts and some 30 in. ones before we got the machine rental bill. The bill appeared to be something over three times what we had expected. It seemed that we had figured on paying per inch diameter cut and the bill was figured on the basis of inches of circumference! This must have been in the fine print somewhere.

At this point it became apparent that it would be quite worth-while to actually own a cutting machine. So, we bought our first machine in December 1952. Since then here is a summary of the cuts made with our own machine in the first three years:

Pipe	*Cuts*	*Pipe*	*Cuts*
12 in.	7	30 in.	16
16 in.	17	36 in.	7
20 in.	33	42 in.	32
24 in.	17	48 in.	8

Figuring the rental cost of a machine to make all these cuts, even using the pipe diameter instead of circumference, it comes out to almost $3,700. This is more than the cost of the machine, in only three years. Figured on the basis of circumference we could have saved by buying three machines.

Soon Found Ourselves Owning Two Machines

After three years of very satisfactory operation of the Wach's "Pipe Saw" we have recently purchased a second machine. The new one is a German-made machine, now sold in this country. Both machines operate on the same general principle. The German machine is, however, much lighter in weight, eliminating the use of hoisting apparatus, as two men can easily set it on the pipe or remove it. Both machines are powered by air motor. Both crawl around the pipe, while a small circular saw cuts through the pipe wall in a single pass around the pipe. One possibility of trouble with both machines is the likelihood that, upon travelling the circumference of the pipe, the machine may not return to exactly the original point of beginning. This is readily avoided, however, if reasonable precautions are taken.

NEW pipe cutting machine being given a yard trial

Since all new cast-iron pipe laid in Portland is cement lined, all saw blades are bought with carbide tips. Many cuts are made before blades must be re-sharpened. Cost of sharpening is small; and, barring accidents, is very infrequent.

As in cold-cutting, the pipe should be well blocked on both sides of the cut to support it. Also, it is important that the wedges furnished be inserted in the saw kerf to eliminate binding. This is particularly true if carbide tipped blades are used, as binding will lift the carbide inserts right out of the blade. Particular care must be taken as the cut is being completed. to see that the severed pipe does not kick and bind the saw or even harm the machine itself.

With these few precautions, the two "pipe saws" have proven extremely satisfactory. Among the advantages are sure-fire quick cuts, accurate cuts to exact length, safe cuts, no cracked pipe, simple to operate almost anywhere, and the easiest pipe cutting yet. As mentioned before, the cost of the machines is easily justified if any cutting of large pipe is to be done. Added to this are further benefits arising from cutting down of labor cost and the minimizing of the spoilage of pipe.

So, in Portland you have to dig deep to find the old cold cutters and then you are faced with the problem of finding anyone to use them. This is what you hear: "Let's wait until the machine gets back from the other job!"

SETTING and adjusting the machine—then, a minute of operation per inch of diameter and the job's done

VIII. TECHNICAL DATA SECTION

IN THE FIELD of water supply and sewage disposal, the engineer, the superintendent, the chemist and the operator all must have some knowledge of certain basic and applied sciences. Of particular importance are bacteriology, chemistry, hydraulics and mathematics; of lesser importance are hydrology, geology, limnology, etc.

Why These Sciences Are Important

In water supplies, bacteria are undesirable. They may be the source of disease, the cause of tastes and odors, or a factor in corrosion. Their elimination or control is an essential part of water purification. In sewage treatment, bacteria may be useful or harmful. In the oxidation processes of secondary treatment they are vital participants, just as they are in the anaerobic digestion of sewage sludge. In both instances, (aerobic and anerobic processes) environmental conditions must be carefully controlled to obtain the optimum desired activity of these organisms.

Other bacteria in sewage are not so desirable, they may cause odors or produce corrosive conditions or be the cause of pollution of water supplies. It is for the purpose of preventing any of these undersirable activities that disinfection is practiced.

Chemistry is important to both water and sewage works operations, not only because laboratory control involves chemical analysis but also because the treatment processes themselves involve chemical reactions. Examples are water coagulation, softening, chlorination, oxidation of organic matter in sewage and the digestion of sludge.

Hydraulics and hydraulic engineering are the fundamental basis of the control of flow of fluids. In water and sewage treatment, flow measurement, flow and pressure control, as well as pumping all involve hydraulics.

No one can question the importance of mathematics in modern life and certainly it is essential to every science and to the operation of any plant. While higher mathematics is useful in many calculations, it is not essential to all water and sewage works operations, but a working knowledge of arithmetic, algebra and geometry is necessary.

Technical Aids

Not every person in the field of water supply and sewage treatment has had or can have a complete knowledge of all these basic sciences, and for those persons there are many technical aids and short cuts which are of great help in applying these sciences to operating problems. Even persons, who are well grounded in the sciences, find need and use for these "tools".

Among these technical aids to the application of these sciences are mathematical and chemical tables, charts, nomographs, graphs, mathematical formulas. These various "tools" may be used to solve all kinds of problems of operation, including chemical dosage, disinfection, bacterial counting, flow measurement and control, distribution system operation, pumping, laboratory operation and, of course, mathematical calculations of all kinds. Naturally not all of these graphs, etc., can be included in one issue, but the following section and similar sections in previous Reference and Data Numbers contain a number of these important aids. Also this section may in some issues contain basic articles on how to handle these various short cuts and technical aids and what uses to make of data collected during the operations of a water supply or sewage disposal works.

References

In addition to having these technical aids available, every water and sewage works office should have a technical library. Such a library should be geared to the needs and operations of the particular plant. Persons in charge of such operations should consult the list of reference books appearing in Section I of this and previous issues of the Reference and Data Number.

Physical Constants of Water

THE ACCOMPANING TABLE shows the basic constants for various physical properties of water. The importance of temperature to many of these properties is evident from the data in the table.

The presence of dissolved or suspended substances in water will change several physical constants, depending on the concentration of substances. Dissolved matter will increase the density of the liquid, raise its boiling point, lower its freezing point and decrease its compressibility. Dissolved matter may or may not lower the viscosity of the water depending on the substance, but generally will lower the vapor pressure.

Dissolved matter will increase the electrical conductivity of water if these substances ionize; inert gases have no effect on conductivity. Suspended matter, especially if finely divided or gelatinous (hydrous) in nature will increase the apparent density of water carrying these substances.

Compressibility, density and viscosity are the most important physical properties in relation to the transportation, distribution and measurement of flow of water. The practically incompressible nature of water has an important bearing on the pumping, measurement and distribution of water.

The design and operation of pumps and flow meters are affected by the factor of compressibility. The volume of water discharged from a system is the same as that introduced, regardless of the loss of pressure due to friction between the two points. It is this continuity of quantity that is fundamental in the measurement of flow.

Density and viscosity affect the hydraulic properties of water, especially where motion, or resistance to it are concerned. Both appear in the Reynolds Number formula as it applies to flow and both are important factors in pumping and flow measurement. Vapor pressure also affects pumping since it reduces the suction lift of pumps.

Property	Condition	Constant
Boiling Point—Sea level	760 mm Hg (14.7 psi)	100°C (212 °F)
—5000 ft.	(12.3 psi)	95°C (203.1°F)
—10,000 ft.	(9.95 psi)	89.9°C (193.9°F)
Compressibility		5×10^{-5} per atmos.
Density —solid (ice)	0°C	0.918 gm/ml
—liquid	0°C	0.99987 gm/ml
	3.98°C	1.0000 gm/ml
	10.0°C	0.99973 gm/ml
	15.0°C	0.99913 gm/ml
	20.0°C	0.99823 gm/ml
	25.0°C	0.99707 gm/ml
	30.0°C	0.99567 gm/ml
	100.0°C	0.95838 gm/ml
Diffusion Coefficient into air		0.193
Electrical conductivity		4×10^{-8} mhos/cm
Dielectric constant		81.5
Freezing point	760 mm Hg (14.7 psi)	0.0°C (32°F)
	1520 mm Hg (29.4 psi)	—0.0075°C
Heat Conductivity	32°F	0.34 Btu/(hr) (sq ft) (°F per ft)
	212°F	0.42 Btu/(hr) (sq ft) (°F per ft)
Heat of Fusion	760 mm Hg	79.6 cal/gm
		143. Btu/lb
Heat of Vaporization	760 mm Hg	542 cal/gm
		970 Btu/lb
Light Absorption—Coefficient of extinction K_e per ft.		
	Red—7200 Angstrom Units	3.2×10^{-1}
	Orange—6125 Angstrom Units	7.7×10^{-2}
	Yellow—5650 Angstrom Units	1.3×10^{-2}
	Green—5040 Angstrom Units	3.1×10^{-3}
	Blue—4730 Angstrom Units	1.6×10^{-3}
	Violet—4078 Angstrom Units	3.1×10^{-3}
Surface Tension	0°C	75.6 dynes/cm
	5°C	74.9 dynes/cm
	10°C	74.2 dynes/cm
	15°C	73.5 dynes/cm
	20°C	72.8 dynes/cm
	25°C	72.0 dynes/cm
	30°C	71.2 dynes/cm
Vapor Pressure	0°C	4.58 mm Hg
	5°C	6.54 mm Hg
	10°C	9.21 mm Hg
	15°C	12.8 mm Hg
	20°C	17.5 mm Hg
	25°C	23.8 mm Hg
	30°C	31.8 mm Hg
	50°C	97.5 mm Hg
	70°C	233.7 mm Hg
	90°C	525.8 mm Hg
	100°C	760.0 mm Hg
Viscosity	0°C	1.792 centistokes
	5°C	1.519 centistokes
	10°C	1.310 centistokes
	15°C	1.145 centistokes
	20°C	1.011 centistokes
	25°C	0.8975 centistokes
	30°C	0.8039 centistokes
	50°C	0.5494 centistokes
	100°C	0.2838 centistokes

Equivalent Pipe Size Nomograph*

by PAUL M. ALBERT

Consulting Engineer, Ann Arbor, Mich.

MANY excellent nomographs have been published for determining the friction head and velocity in water pipe lines. For a single pipe size and a given length of pipe, the calculations are simple but where more than one size is involved (series or parallel pipes) the work involved may be quite complex and often tedious.

To simplify such calculations the "Equivalent Pipe" method is often used. With this method one enlarges or reduces some or all the pipes and combines them into a single pipe which has "equivalent" hydraulic characteristics. From this point on the equivalent pipe may be used instead of the actual pipes for calculation of the head loss and flow rate of the network, thus greatly reducing the work in solution of the problem.

The accompanying chart contains two nomographs, one to use for Series Pipes and one to use for Parallel Pipes. The Series Pipe nomograph uses three vertical lines, (H) for head loss, (d) for diameter of pipe, and Length. The Parallel Pipe nomograph also uses three vertical lines (Q) for gpm or cfs, (d) for diameter of pipe, and Length. Both use the same vertical line for Length. For a given problem, when using the chart for either series or parallel pipes use ONLY pipe diameters to the left, or to the right of the vertical line for (d), do not interchange in any one problem. Two ranges of (Q) are shown, 250 gpm and 500 gpm, for the Series Pipe (d) and two ranges are shown for (H) of 10 ft and 50 ft for the Parallel Pipe (d). This allows the user to choose values of (d), one side or the other, which better fits the problem and enlarges the useful range of the chart.

Single Pipe Equivalents

Many hydraulic problems occur where it would be convenient to change just one pipe to an equivalent pipe which would be of the same size in diameter as the rest of the pipes in that group, either series or parallel or even more complex. This may be done quickly by means of the Series Pipe nomograph of three vertical lines marked Series and Length. Connect the actual length and diameter and find (H). Holding that (H) connect (H) and the desired diameter of the equivalent pipe and find the new equivalent Length. This size and length being the equivalent pipe it may be substituted for the actual pipe for further analysis.

Series Pipe Equivalents

As above, find (H) for each pipe in the series, add each to find the total (H). Connect the total (H), the desired diameter and find the new Length. This is the length and diameter of the "Equivalent Pipe" which, for computation purposes, greatly simplifies further calculations. *Example*-1. Given three pipes in series as shown:

Using the Series Pipe nomograph lines

Pipe	*Size*	*Length*	*Q*	*Find H*
A-B	8 in.	600 ft	500 gpm	5 ft
B-C	6 in.	300 ft	500 gpm	10 ft
C-D	10 in.	800 ft	500 gpm	2 ft
A to D			total	17 ft

Assuming that an 8-in. diameter pipe will be suitable for the equivalent pipe, hold 17 ft for (H) and connect to 8-in. for (d) and find the length to be 1900 ft. This is the size and length of the equivalent pipe which may now be used for further calculation in place of the actual pipes. Other diameters could have been selected for the equivalent pipe and the length would also change. If the whole length of the series, 1700 ft actual, had been used to find the equivalent diameter, the diameter would usually fall somewhere between the nominal pipe sizes and therefore would be less easy to use.

Parallel Pipe Equivalents

Similar operations are performed to find an equivalent pipe for parallel pipes and just as simply. *Example*-2, Given two pipes in parallel as shown:

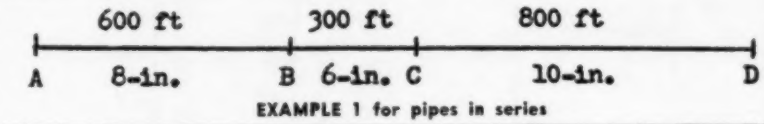
Using the Parallel Pipe Nomograph lines

Pipe	*Size*	*Length*	*H*	*Find Q*
ABCD	6 in.	1600 ft	10 ft	200 gpm
AD	8 in.	800 ft	10 ft	630 gpm
Both pipes			total	830 gpm

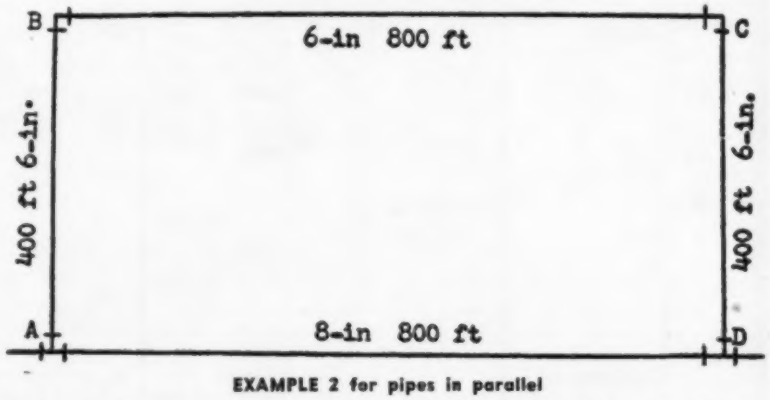
Assuming the diameter as 8-in for the equivalent pipe, connect 830 gpm and 8-in.-diameter and find the length to be 480 ft. This is the equivalent pipe and the head losses at other flows is easily calculated.

Series-Parallel

If, in the example of parallel pipes, one of the parallel pipes were to be three pipes in series (say as in the example of series pipes) the chart provides an unusually rapid means of simplification. Find the equivalent pipe for the series of three pipes. Use the series equivalent pipe and the remaining parallel pipe as two parallel pipes and find the parallel equivalent pipe. This is the equivalent pipe for the series-parallel group and further computations of friction and discharge through this network is simple.

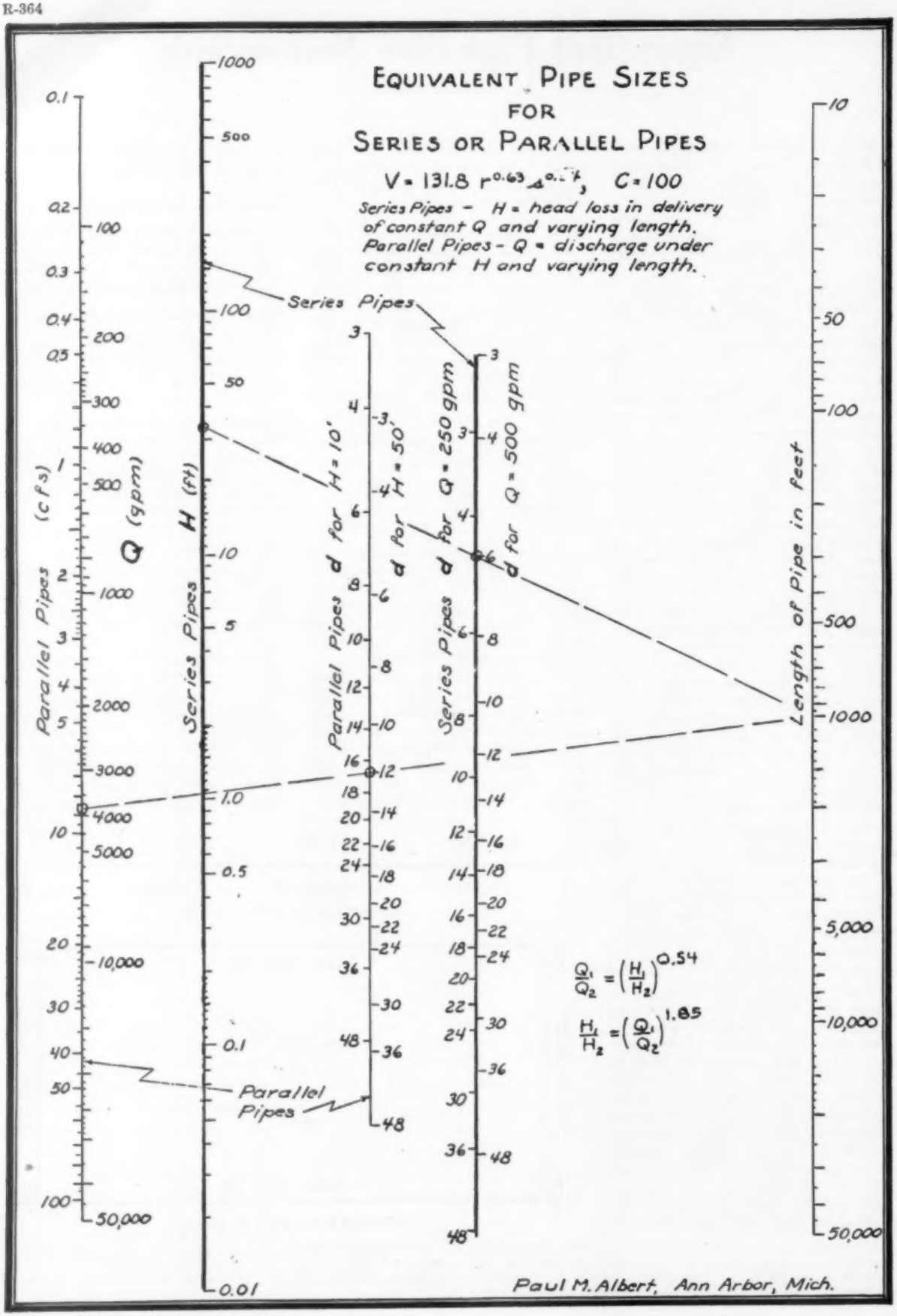


EXAMPLE 1 for pipes in series



EXAMPLE 2 for pipes in parallel

* The nomographs are based on a C-Value of 100. Where other C-values are to be used but all pipes have identical C-value the chart may be used without regard to the C-value and when the equivalent pipe is found it may then be evaluated in terms of the correct C-value.—Two equations in terms of H and Q are provided on the chart which may be used to compute flows at other head losses or head loss at other flows than those contained in the nomographs.


EQUIVALENT PIPE SIZES
FOR
SERIES OR PARALLEL PIPES
V = 131.8 r^0.63 Δ^0.54, C = 100
Series Pipes - H = head loss in delivery of constant Q and varying length.
Parallel Pipes - Q = discharge under constant H and varying length.
Series Pipes
Parallel Pipes
Parallel Pipes (cfs)
Q (gpm)
Series Pipes H (ft)
Parallel Pipes d for H = 10'
d for H = 50'
Series Pipes d for Q = 250 gpm
d for Q = 500 gpm
Length of Pipe in Feet
Q1/Q2 = (H1/H2)^0.54
H1/H2 = (Q1/Q2)^1.85
Paul M. Albert, Ann Arbor, Mich.

How to Collect, Store and Use Data

by JAMES M. SYMONS and GEORGE E. SYMONS

Respectively Instructor in Sanitary Engineering at Mass. Inst. of Tech., Cambridge, Mass., and Consultant & Technical Editor in Larchmont, N. Y.*

THE OPERATION of water treatment, sewage disposal, garbage incineration, and industrial waste plants involves the collections, storage, and use of numerical data. Data must be recorded. Attempts to correctly remember masses of data will lead only to error. To be of any value in operation, data must be compiled in a manner which is useful for operational control.

Data must be collected to meet legal requirements or to satisfy the directives of municipal officials but of what real value are piles of dusty books containing records of years ago? It is not suggested that every piece of data collected must be put to daily use in order to be worth collecting. It is suggested, however, that much of the data collected could be used to help an operator with his daily work, whereas it is merely filled "for future reference" because the operator is not always familiar with all of the mathematical tools available to arrange the data in useful form.

A Basic Question

As one approaches the subject of data utilization, specific questions may be asked such as: Of what use is a pie chart? How does a line graph differ from a bar graph? What is a nomograph? etc. Before answering such questions it is desirable to answer a more general, but fundamental question—how do I use data?

The first step in preparing data for use is to decide what information is of interest; for example: Pounds of alum to be added related to flow, turbidity of influent related to rainfall; on what is the maintenance dollar spent?; dissolved oxygen in the aeration tank related to hours of the day, and so forth. The second step is to collect the specific numerical data needed. Comparison of these data with the outline given below will show whether a table, chart, diagram, graph or nomograph will present the data in the most useful manner. Finally, the appropriate mathematical tool should be employed.

Tools Available

The purpose of this article is to examine five mathematical tools most useful to the operators of sanitary engineering facilities. The discussion of each will contain: Areas of applicability, methods of construction, and examples. The five tools to be examined are defined for the purpose of this article in the following manner:

1. Tables—A representation of data in condensed tabular or columnar form.

2. Charts—A pictorial representation of data or physical conditions.

3. Diagrams—A schematic representation of complex patterns of flow, either in the physical sense or as in chain of command.

4. Graphs—The representation of the inter-relationship of two or more items, one with the other.

5. Nomographs—An alignment chart consisting of three or more scales so arranged that a straight line between any two points on two scales will cut the third scale at a point bearing a mathematical relation to the other two points. In short, the nomograph is a graphical tool for the solving of problems.

In common usage the terms chart, diagram, and graph overlap and are often used to describe the same item. Here, however, they will be treated separately.

Tables

A table is a condensed tabulation of data or information. It consists of two or more, columns of entries, the first column of which contains the name (or symbol) or the numerical value of some entity under a basic set of conditions. Other columns may contain values of the basic entity under other conditions which may be applied to it.

Tables are, by definition, columns of numbers. The mind cannot visualize the relationship of quantities from a list of numbers; therefore, one must be careful to use tables where exact values of one variable with respect to another are desired, not where an overall trend is sought.

How To Make a Table

To construct a table one chooses the independent variable, that is, the quantity which the operator can select at will. For example, in a table of squares and square roots of numbers, the number itself is the independent variable since the person using the table chooses the number in which he is interested, independent of the other numbers in the table.

The independent variable is generally placed in the most left hand column of the table under a suitable heading and is usually entered in the table as a "whole" or "round" number. Other numbers in the table are the dependent variables, so-called because their value depends on the selection of the independent variable. In the case of the square root table there are two dependent variables, which are placed in properly headed columns to the right of the independent variable column.

Example: The Table of Squares and Square Roots of Numbers

Number	Square of Number	Square Root of Number
0	0	0
1	1	1.0
2	4	1.4142
3	9	1.7321
4	16	2.0000
5	25	2.2361

Interpolation

As mentioned above, the independent variable is usually placed in the table as a whole number. Sometimes, however, one desires information about a number between the whole numbers. For example, knowing that three feet contain 36 inches and four feet contain 48 inches, how many inches are contained in 3-1/6 feet? The process of finding the answer is

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termed interpolation. If three feet equal 36 inches and four feet equal 48 inches, 3-1/6 feet must equal the number of inches one-sixth of the distance between 36 and 48 inches, or 36 plus one-sixth of the number of inches from 36 to 48. Therefore, 3-1/6 feet equal $36+(48-36)/6$ inches or 38 inches. This is straight line interpolation.

One should be warned here against the use of straight line interpolation with variables which are not linearly related. For instance, one might suppose that the square of 4.5 is halfway between 16 and 25 or 20.5 Actually 4.5 squared is 20.25, and the use of 20.5 would introduce an error of 1.25 per cent. This percentage error becomes smaller as the numbers rise in value; therefore, it is not too significant in this particular case, but this type of error should be kept in mind when employing interpolation.

Other examples of useful tables in Sanitary Engineering are:

- Alkalinity equivalents of various chemicals
- Analysis of sewage sludge
- Areas of circles
- Atmospheric pressures at various altitudes
- Btu/ton of refuse—related to moisture content
- Carrying capacity of different size sewer pipe at various slopes
- Characteristics of chemicals
- Conversion factors from one system of measurement to another
- Degrees of hardness of water
- Equivalent weights and measures
- Fire flows required for various size cities
- Fire stream discharges for various nozzle sizes
- Friction of water pipes at different flow rates in different size pipes
- Logarithms of numbers
- Pipe Line capacity under different heads
- Pressure to head relationship
- Squares and square roots of numbers
- Temperature Conversion from °F to °C and vice versa
- Trigonometric functions
- Velocity of flow in pipes of different sizes at different flow rates
- Water requirements of various industries

Charts

Charts differ from tables in that they show pictorally the relation of one item to others or the value of some entity in terms of another. They are particularly useful for explaining data to persons not familiar with a technical subject and are helpful in presenting annual reports to boards and commissions as well as to newspapers.

In general, charts fall into two categories, those in which some geographical features are shown and those in which some entire quantity is divided up into parts, either by percentage or by actual value.

For example, if one were trying to explain that additional maintenance help at a plant was required, a *pie chart* would be an excellent method of showing how a typical working day is utilized. The quantity to be sub-divided would be an eight hour shift. A circle; i.e., a pie is divided into various sections: Sampling, operation, maintenance, clean up and meals. A time study would reveal how much of the eight hour shift the operator spends in performing each of these four duties.

Time spent is converted to percentage and the pie is split up so that the area of each of the four sections of the pie appears as a per cent of the whole area of the circle equal to the per cent time spent on the corresponding job. This operation is easily performed by using a protractor and remembering that every 3.6 degrees of a circle forms a wedge containing 1 per cent of the area. A pie chart such as this would indicate at a glance that a high proportion of the operators' time was spent at maintenance and would show the need for additional employees. The data used for developing the pie chart might be as follows:

Record at Plant

Job	Hours per Shift	Per Cent
Sampling	1	12.5
Operation	2¼	26.9
Maintenance	4	50.0
Clean up and Meals	¾	10.6
Total	8	100.0

The actual pie chart to fit these data is shown in Fig. 1.

The pie chart is useful particularly related to chlorine dosage; therefore, to indicate sources of revenue and disbursement of money for expenses. Other types of charts are:

Calendar charts which indicate schedules of dates on which repetitive action is required for proper operations. An important chart of this type is the schedule for preventive maintenance operations.

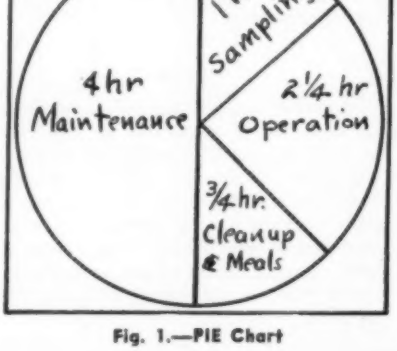

Fig. 1.—PIE Chart

Line charts in which a single line or narrow bar is divided into parts with the divisions being marked with numerical values of the entity or its divisions under consideration. Examples of line charts are: pH zones or ranges of indicators; zones or ranges of pH in which chemical reactions in water or sewage take place; pH zone in which corrosion actions occur; geological strata as shown by well logs, etc.

Map charts consist of a map of some geographical section on which are shown special conditions or facts. Such charts may show weather conditions, contours, ground water elevations, geological strata, distribution system pressures, etc.

Diagrams

A diagram is an outline, plan or drawing intended to show what something is or how it works. One of the most common is the "flow diagram" which can be used for such diverse purposes as family trees, delegation of authority within an organization, or the sequential progress of process operations as in the flow of water or sewage through a water supply or sewage disposal system or through the individual processes of a treatment plant, or of refuse through a composting plant.

To construct a diagram of liquid or solid flow through a processing plant each step in the treatment may be represented by a simple labeled box, or an accurate scale drawing of the equipment. Although in actual practice the flow through a plant may change direction many times and even double back on itself, in a flow diagram the process is laid out in a straight line. Other data may be included at pertinent points, e.g., the detention time at each step, the cumulative time up to that step, or the time remaining until the process is completed, may be noted at that step. Usually chemical addition or waste removal is noted at the appropriate stage. A flow diagram through a conventional water supply system might be as shown in Fig. 2.

Graphs

Graphs are divided into two classes; line graphs and bar graphs. Line graphs are pictorial representations of tabular data showing how one quantity varies with respect to another. A bar graph is the pictorial representation of quantities which are not continuous variables of one

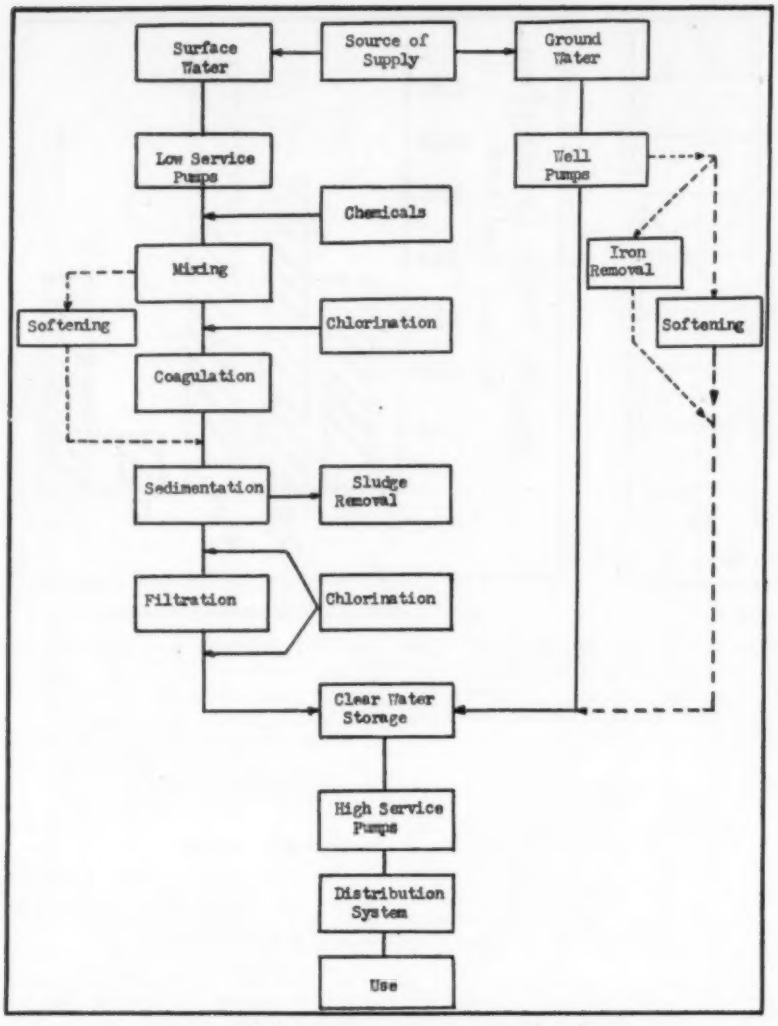

Fig. 2.—FLOW diagram of water supply system

another. For example, a graph of the water consumption per year in various cities around the country would be developed as a bar graph. Each city is independent of the next and all start at zero water consumption each year reaching some final total on December 31. A line connecting the plotted data would be meaningless.

Line Graphs

On the other hand, line graph would be used to plot such data as bacteria per ml remaining at the end of a ten minute contact time for various chlorine doses. In this case, all of the samples started with the same number of bacteria per ml and the number remaining may be directly related to chlorine dosage; therefore, a line graph is used. (Note: This is only an example and assumes that chlorine dose is directly related to bacterial kill; this may or may not be true).

To construct a line graph the decision must be made as to the independent and dependent variable. The choice is made on the same basis as mentioned in the discussion of tables. The independent variable is placed along the horizontal axis of the graph, termed the abcissa or "X" axis. Equal divisions to a convenient scale are marked off, and the values are labled both by name and units. The dependent variable is then plotted along the vertical axis. This axis is termed the ordinate or "Y" axis. Here also a convenient linear scale is chosen, numbered and labeled as to quantity and units. The title is usually placed at the top center or upper right hand corner of the graph. The title generally reads "Graph of Dependent Variable (Name) vs. Independent Variable (Name). Other pertinent information may be included. A graph of chlorine residual vs chlorine dose, for example, would appear as shown in Fig. 3.

Bar Graphs

A bar graph is similar to a line graph in many respects. The varying quantity is plotted up the vertical axis and is labeled in the same manner as above. The various items to be placed along the horizontal axis are spaced to make the graphs easy to read and the spacing has no numerical value. The axis is also labeled and the graph is generally titled in a manner as outlined above. The graph of water consumption of various cities in the country would appear as shown in Fig. 4.

Before leaving the subject of arithmetic graphs, that is graphs in which the graduations of the axes are linear, it would be well to discuss some of the more specialized problems of graph construction. Two problems of interest are: 1) How to represent large numbers, and 2) When to leave the zero or origin point off the graph.

The problem of how to place large number on a graph without cluttering up the scales with zeros can be solved many different ways. The simplest, however, is to chose some common factor, hundreds, thousands, millions, etc., that appear in each figure and to remove it, leaving convenient numbers on the axis. Care must be taken to make note of this process when the units of the axis are stated.

For example, a graph of The Population in the United States vs. Years would have millions removed along the population axis for convenience as in Fig. 5. Figure 5 illustrates the other point, when to leave zero off of the graph. Most graphs are drawn on 8½ by 11 inch paper. By placing population along the eleven inch side of the paper and by discarding the unused population numbers, that is zero to 75 million, the remaining figures can be stretched to make the curve rise very steeply. This can be mis-leading to the uninformed.

A more accurate picture of the growth of population in these United States would be given by a graph with all of the population axis presented. Therefore, when it is desirable to present an accurate picture of conditions to the layman it is wise not to try axis stretching. For technical use around the plant, however, it is foolish not to make graphs as accurate and usable as possible by stretching the scales as much as possible. To include any unused portions of either axis is a waste of space.

Meaning of Slope

An important concept to understand is the slope of a graph. Slope is defined as the change of the de-

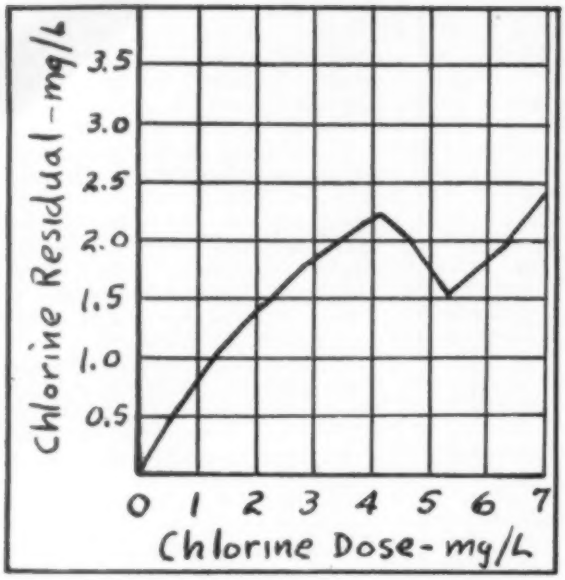

Fig. 3.—LINE graph of chlorine residual

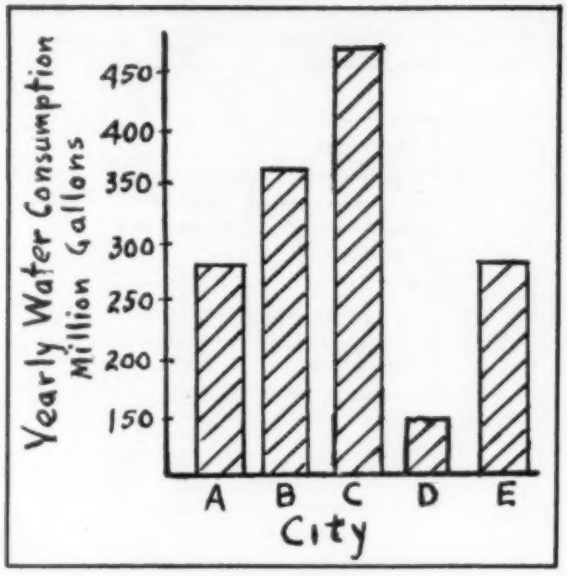

Fig. 4.—BAR graph of water consumption

pendent variable for a unit change of the independent variable. This means that the slope of a curve is the rate or change of the dependent variable. For example, in the laying of mains or sewers, the term "per cent grade" (slope) is used. A water or sewer with a 6 per cent grade or slope rises or falls six feet in elevation in every 100 feet of horizontal length. The rate of change of the elevation of the pipe invert is six feet per 100 feet of length.

Figure 6 shows an example of pump operating costs versus daily pumpage. If the rate of increase in operating costs per unit of pumpage is required, it is necessary to determine the slope of the curve (straight line). This is done by dividing the rise of the line by the corresponding run. In this case distance "A" ($20 per day) is divided by distance "B" (3.3-1.1mgd, or 2.2mgd pumped). The slope then is $20/2.2 or $9.09 per mgd pumped.

Equations of Graphs

The graphs disscussed thus far have been of the linear type, that is "y" the dependent variable, is equal to "x" the independent variable, times the slope "m"; This relation may be expressed by the equation, $y=mx$.

In some cases the plot of the data does not pass through the zero point on both axes. That is, when the "x" value of zero, the line passes through some value on the y intercept other than zero; this value is termed the "y" intercept and this intercept is expressed as "b" in the equation which then takes the general form for linear graphs of $y=mx+b$.

Often the general equation of the measured data does not agree with the straight line form.

Logarithmic Graphs

Two alternate general equations which are often used to represent data are: $y=a^x$ and $y=x^m$, where "a" and "m" are constants. Examining the first of these alternate equations, it is seen that taking the logarithm of both sides of the equation yields $(\log y)=(x)\ (\log a)$. The quantity "log a" is a constant of some numerical value; therefore the equation really is $(\log y)=(K)(x)$. This equation is of the linear or straight line type if "log y" were plotted on the "y" axis and "x" on the "x" axis.

It would be a tedious procedure to have to obtain the logarithm of the

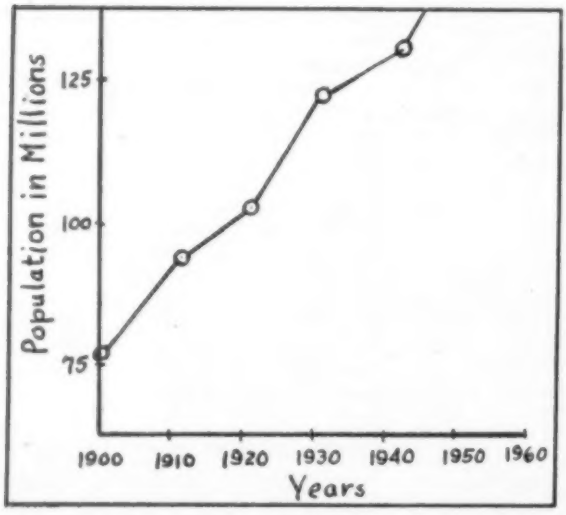

Fig. 5.—LINE graph showing y intercept and large numbers

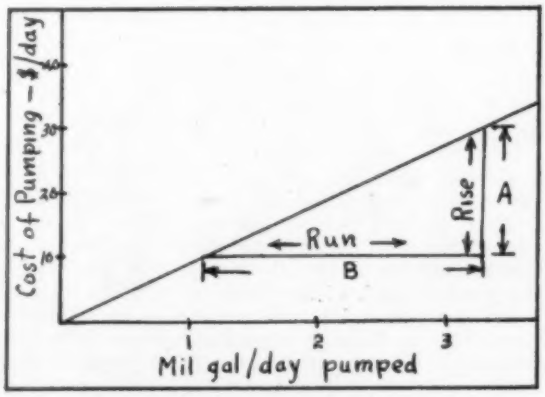

Fig. 6.—LINE graph showing meaning of slope

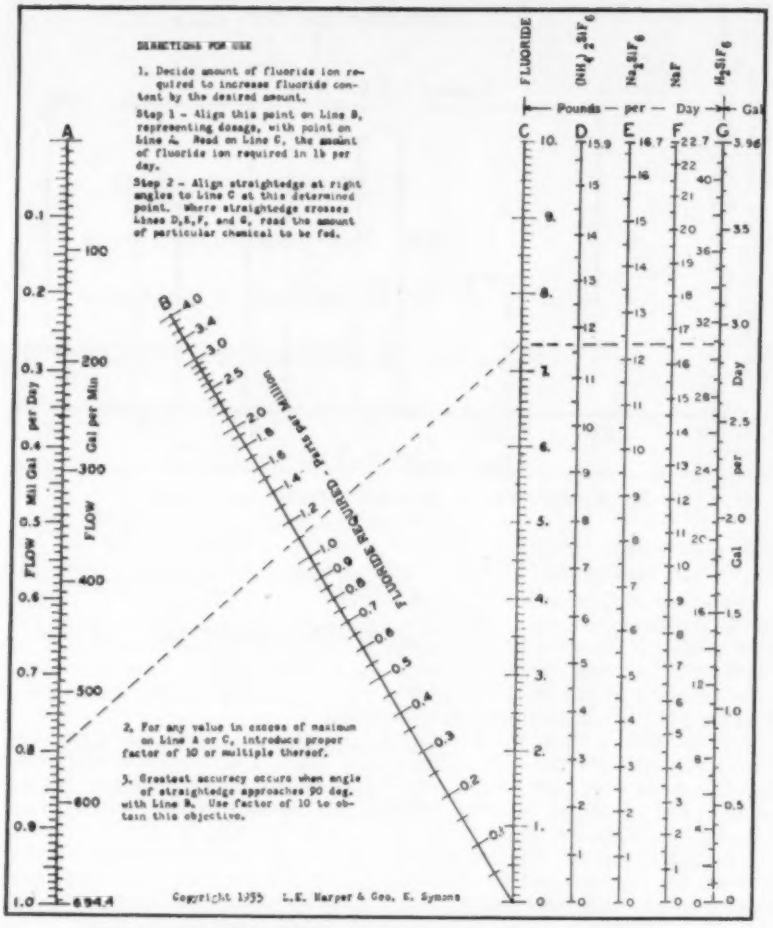
DIRECTIONS FOR USE
1. Decide amount of fluoride ion required to increase fluoride content by the desired amount.
Step 1 - Align this point on Line B, representing dosage, with point on Line A. Read on Line C, the amount of fluoride ion required in lb per day.
Step 2 - Align straightedge at right angles to Line C at this determined point. Where straightedge crosses Lines D,E,F, and G, read the amount of particular chemical to be fed.
2. For any value in excess of maximum on Line A or C, introduce proper factor of 10 or multiple thereof.
3. Greatest accuracy occurs when angle of straightedge approaches 90 deg. with Line B. Use factor of 10 to obtain this objective.
FLUORIDE
$(NH_4)_2SiF_6$
Na_2SiF_6
NaF
H_2SiF_6
Pounds — per — Day
Gal
FLOW Mil Gal per Day
FLOW Gal per Min
FLUORIDE REQUIRED - PARTS PER MILLION
Day
Gal
Copyright 1955 L.E. Harper & Geo. E. Symons

Fig. 7.—EXAMPLE of Z type alignment chart for fluoridation

dependent variable for each datum point before plotting, therefore special "semi-log" graph paper has been devised so that both variables may be plotted directly and straight line graphs will result.

A typical curve of the "semi-log" type is obtained by plotting the Per Cent Transmission vs. Concentration for use in determining unknown concentrations of some ion by the standard colormetric tests using a spectrophotometer. The equation of the curve is log (%T)=(K)(Concentration), a straight line on "semi-log" graph paper.

The second equation above, $y=x^m$, becomes $(\log y)=(m)(\log x)$ when the logarithm of both sides of the equation is taken. In this case to obtain a straight line on arithmetic paper the logarithm of both the dependent and independent variable must be computed and plotted. Again this is inconvenient and special graph paper, "log-log" graph paper, has been developed to allow direct plotting of both variables.

An example of the "log-log" type equation is that for pipe flow; $H_L=(K)\ (Q^{1.85})$. In logarithmic form this becomes $(\log H_L)=(1.85)(\log Q)+(\log K)$. It is seen that this is the typical $y=mx+b$ type of equation. Plotting Head Loss vs. Flow on "log-log" graph paper yields a straight line.

Nomographs

An alignment chart, also termed a nomograph or nomogram is one of the most useful mathematical tools available to an operator. The simplicity of using such charts has made them quite popular, both with non-technical and technical personnel.

Alignment charts are used to show the relationship between three, four, and five or more variables and are particularly useful in plant operation where it is possible to calculate operation results, quickly and easily. Such calculations as pounds of chemical dosage determined from flow rate and dosage rate, or production quantities from analytical data, per cent removals, rates of flow and many other items are among the useful information that can be calculated by alignment charts.

The simplest alignment chart consists of three parallel lines each of which has a scale representing one of the variables in the mathematical equation or relationship to be solved. The scales, however, do not have to be parallel and may in fact look like a Z or have some other angular, curved or spacial relations.

In the discussions above, the construction of diagrams and graphs utilized graphical scales. Graphical scales may be either curved or straight lines graduated with a set of numbers arranged in order of magnitude. When the distances between points are equal, it is termed a uniform scale; when the distances are unequal, it is a non-uniform scale.

Unlike graphs and diagrams, nomographs or alignment charts do not make use of graphical scales but employ instead, what are termed "functional" scales. In a "functional" scale the distances between the graduations are proportional to the value of the variable being sought. Frequently, a logarithmic scale is employed to establish this proportionality, although other proportionality factors may be used. In alignment charts the distances are laid off from an initial point on the scale, not necessarily the zero point.

How to Make a Nomograph

The construction of alignment charts can be a complicated art for complicated relations, but for the usual calculations in a water, sewage, or waste plant, the development of a useful alignment chart is relatively easy.

For a short cut to the construction of a parallel alignment chart (for example relation of flow, chemical dosage and dosage rates) follow these steps:

1. Draw two parallel lines a convenient distance apart.

2. Graduate one scale (A) from top to bottom in logarithmic divisions to cover the entire range of values to be covered by the data collected on one variable, say flow in mgd.

3. Graduate the second scale (B) in logarithmic divisions for the entire range of values to be covered by the second variable, say pounds per 24 hours of chemicals.

4. To determine the location of the third "C" scale (dosage in ppm) draw two light guide lines, one connecting the top value on scale A with the bottom value on Scale B, and the other connecting the bottom value on scale A with the top value on scale B. Where these lines cross, draw a

vertical line parallel to lines A and B.

5. To determine the scale divisions on scale C, place a straightedge across the upper part of scales A and B for two particular values and mark the point where the straight edge crosses line C. Calculate the value of this point from the equation ppm (dosage rate) = (lb/day ÷ (8.34 x mgd)

Repeat this operation for two values on scales A and B, in the lower parts of the scales.

Having located two values on scale C, divide the distance in between the two points into the number of divisions representing the number of whole values between the two values. These divisions may be logarithmic or approximately, but not necessarily, so.

Some persons prefer to use scale divisions which are equal in value. This arrangement can be accomplished for at least two scales by using a Z type nomograph as shown in Fig. 7. In this case, the "C" scale is divided in approximately logarithmic divisions. To locate the points on this scale it was necessary to calculate the value for each point for two different rates of flow and locate it graphically by straightedge connecting those two different flow rates with the dosage in lb per day for that dosage rate and those two flow rates. Where the lines crossed represents the location of the value in ppm on the "C" scale. This is a somewhat tedious procedure but effective.

In Fig. 7, more than one scale is included in the B scale as may be done in many cases.

Some Mathematical Terms of Importance

To complete the mathematical picture, it is desirable to define four common terms: 1) Average, 2) Mode, 3) Range and 4) Median.

All of these terms attempt to "tell a story" about experimental data without presenting all of the data taken. Suppose an operator measures the suspended solids in an aeration tank every day at 11:00 a.m. and suppose the superintendent wishes this information. By reporting the average, mode, and range of the data to the superintendent, he will have all of the information required without having to examine all of the data. These quantities give a picture of all of the data.

The *average* of data is the sum of all of the data divided by the number of pieces of data present. The average assumes the natural variation in data will cancel itself out, that is there will be the same number of high results as low ones. This may or may not be true, but the average of data is an important property. The "average" is also termed the "mean".

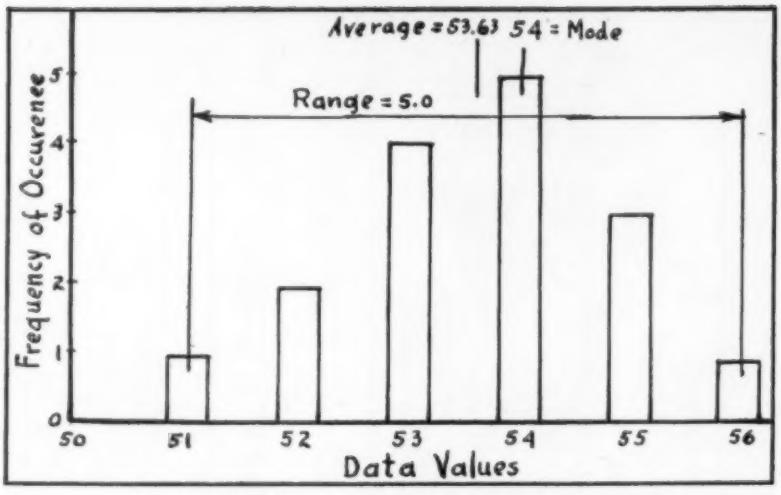

Fig. 8.—EXAMPLE of "average," "mode" and "range"

The *mode* of data is the value of the data that appears most frequently, that is, it is the most likely to appear. As an example, the mode is the value reported by the Most Probable Number (MPN) of microorganisms. The mode differs from the average by the fact that the mode is not affected by a few very high or very low results. For example, in the data 2,2,3,5,5,5,5,5,7,30 the mode is five, but the average is 6.9. The difference between the two values would indicate that some very high values were present, as is the case.

All data has some scatter, that is, there are some high and some low results. *Range* is a measure of this scatter. The range of data is the difference between the highest and lowest numerical value. Range is a good measure of the natural variation of data except in the cases of tests where a single piece of data could be grossly in error. This error will cause an undesirable increase in the range and it will no longer be a good representative of the consistency. These cases, however, do not occur frequently.

If the average value of suspended solids in an aeration tank is 1500 mg/L and the range is 500 mg/L this means that all of the values of suspended solids measured would lie somewhere between 1250 and 1750 mg/L.

These three quantities (average, mode and range) are shown in Fig. 8. A combination of all three will tell much about the characteristics of data.

In cases where daily data are tabulated for the month or the year, some operators use the median value as being more representative of the true "average" condition for the month than the arithmetical average. The "median" is that value which lies midway in numerical sequence between the highest and the lowest value; for example the sixteenth value in a list of 31 numbers when listed in descending or ascending order of numerical value.

In many cases the *weighted average* value is of far more importance than the arithmetical average. For example, to obtain a weighted average suspended solids in ppm it is necessary to calculate total pounds of solids per day from daily flow and ppm; these values are then added and divided by the sum of the flows (times 8.34) for the period (say a month). This operation gives the weighted suspended solids in ppm for the month.

Summary

In the short space of one article, it is not possible to develop all of the details of how to collect, store and use data. Neither is it possible to cover the subject of mathematics as it is used and useful to water and sewage plant operators. This article has not attempted to do either, but has been developed to acquaint the reader with some of the most useful tools with respect to data handling.

The mathematically minded student and engineer will find most helpful and useful this book on alignment charts:

"Nomography" by A. S. Levens, published by John Wiley & Sons.

Also students, operators and engineers will find these two articles both helpful and interesting.

"Graphical Approach to Statistics" by C. J. Velz; *Wat. & Sew Wks.* 99: R-106 (April 1952)

"Survey of Elementary Mathematics" by Warren K. Eglof; *Wat. & Sew Wks.* 95: R-55 (April 1943)

NOTE THE NUMBERS

they correspond with the

headings in Section IX on

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IX. BULLETINS and CATALOGS

For Copies of any of the Bulletins or Catalogs Listed Below, Circle the Corresponding Numbers on the Inquiry Reply Card in this Section.

1*R*

Acid Handling Pump—This 6-page bulletin describes the design features, corrosion-resistant materials of construction, applications, sizes and capacities of this acid handling pump.—Dorr-Oliver Inc.

2*R*

Activated Silica Sols Preparation—Series Sheet "A" covers jar test procedures for preparing activated silica sol from sodium silicate and ammonium sulfate as the reacting chemical. Sheet "B" retails procedures for batch preparation of activated silica sol with such reactants as ammonium sulfate, alum, chlorine etc. Illustrations show flow diagrams.—Philadelphia Quarts Co.

3*R*

Activated Sludge—A technical study on the Kraus Process covers the dual aeration system for power savings and sludge interchange for beneficial use of supernatant liquor and elimination of bulking. Actual plant data. Design considerations.—Pacific Flush Tank Co.

4*R*

Activated Sludge—Catalog 100 describes the Cavitator for installations up to design populations of 1,000.—Yeomans Brothers Co.

5*R*

Activated Sludge Plant—The "Biosorption" activated sludge plant is illustrated and discussed in this bulletin. The plant incorporates efficient means of oxygen transfer which reduces the retention time within the aeration basins.—Infilco Incorporated.

6*R*

Aer-Degritter—This brochure gives detailed information on the company's Aerated Grit Removal System.—Chicago Pump Co.

7*R*

Aeration Equipment—These bulletins cover the Wide-Band Aeration System, featuring swing diffuser units and precision diffuser tubes.—Chicago Pump Co.

8*R*

Aeration Equipment—This booklet presents complete information on the development, design and application of both Walker Diffusair and Impingement aeration equipment. It includes discussions on channel aeration, grit aeration and details on the Walker Air Lift for return activated sludge pumping.—Walker Process Equipment Inc.

9*R*

Aerators—This bulletin gives a brief outline of the reasons for aeration and describes the Cascade Aerator, Coke Tray Aerator, pressure Aeration—(Atomerator), Degasifier and Deaerating Heaters.—General Filter Co.

10*R*

Aerator Clarifier—Bulletin 129 gives detailed information on the small compact activated sludge sewage treatment unit, to handle up to 500,000 GPD.—Chicago Pump Co.

11*R*

Air Compressor—Catalog 5540 presents the heavy Pneumatractor, a 135 cfm gasoline engine driven air compressor built into a wheel tractor. The catalog describes the use of a backhoe, front end loader, rotary brush, and dozer blade in conjunction with the compressor.—Schramm, Inc.

12*R*

Air Relief Valve—Bulletin F illustrates and describes the Rensselaer combined air and vacuum and air release valve.—Ludlow Valve Mfg. Co., Inc.

13*R*

Algaecide—A new simple, low-cost way to stop algae problems in cooling systems through use of No. 120 series algaecide is described in this bulletin.—Allis-Chalmers Mfg. Co.

14*R*

Aluminum Elevated Water Tank—This reprint describes the construction of an aluminum all-welded elevated water tank.—Graver Tank & Mfg. Co., Inc.

15*R*

Automatic Control—This catalog contains brochures on Transistorized Tone Generator type control systems, a 4-page case history on a water works control system, and information on data logging system.—Taller & Cooper Inc.

16*R*

Automation—This bulletin discusses automatic control of filter operation with interlocking safety devices to prevent overflow of clearwell or dangerously low filter levels. It presents the "C.-A.-P. System" instruments.—Infilco Incorporated.

17*R*

Asbestos-Cement Pipe—A brief history of the use of asbestos and the advantages of "Century" asbestos-cement pipe. A chart of standard sizes and classes is included.—Keasbey & Mattison Co.

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18*R*

Bacteria Free Packing—A descriptive leaflet on Fibrex, an approved sanitary packing.—Hydraulic Development Corp.

19*R*

Ball & Socket Cast Iron Pipe—This bulletin describes the Clow ball & socket cast iron pipe for river crossings and other uses where full 15-degree turning deflection is required.—James B. Clow & Sons, Inc.

20*R*

Bar Screens—These two bulletins discuss and illustrate Rex Heavy-Duty Bar Screens and front-cleaned bar screens. —Chain Belt Co.

21*R*

Bar Screens—This catalog covers the screening of sewage in both small and large plants. Also included are data on traveling water screens.—Jeffrey Mfg. Co.

22*R*

Barminutor—This bulletin illustrates and describes advantages, principles of operation, applications, mechanical descriptions, detailed specifications and other information on the company's Barminutor comminuting machines for use in rectangular channels.—Chicago Pump Co.

23*R*

Bascule Gate—A 12 page bulletin with dimensions, description and typical installations of this crest gate for pond level and flood control.—S. Morgan Smith Co.

24*R*

Biofilters—Bulletin 7313 describes small scale biofiltration with Dorr-Oliver Duo treatment units providing complete sewage treatment for institutions, housing developments and turnpike service areas. —Dorr-Oliver Inc.

25*R*

Biological Oxidation Plant—The "Aero-Accelator" biological oxidation plant is the subject of this bulletin. This compact unit is said to produce high percentages of suspended solids and BOD removal.—Infilco Incorporated.

26*R*

Blowers—This bulletin contains sectional views, typical installations, performance characteristics, specifications and illustrations of large rotary positive displacement blowers and exhausters.—Roots-Connersville Blower.

27*R*

Brinemaker—This catalog illustrates and describes various types of brine making tanks and wet storage systems available to salt users.—Morton Salt Co.

28*R*

Cast Iron Pipe—This illustrated booklet provides pictorial proof of the ruggedness and durability of cast iron pipe in water supply and distributions; sewer mains; and industrial service.—Cast Iron Pipe Research Assn.

29*R*

Cast Iron Pipe—Complete line of Cast Iron Pressure Pipe in sizes of 3 to 24 inches diameter is listed in catalog 54. Complete specifications and construction details.—Alabama Pipe Co.

30*R*

Cast Iron Pipe—Catalog gives full details of weights and dimensions of "Sand-Spun" centrifugal cast iron pipe, cast iron fittings and specialties.—R. D. Wood Co.

31*R*

Cast Iron Pipe in Sewerage Systems—This 52 page booklet shows instances of the use of cast iron pipe in sewerage systems.—Cast Iron Pipe Research Assn.

32*R*

Catch Basins—Several styles and sizes of catch basins are described. The bulletin also states that special lettering is available.—Clarksville Foundry & Machine Works.

33*R*

Cathodic Protection—A series of three bulletins on cathodic protection: "Fighting Corrosion with Corrosion", "Cath-O-Chem System", and "Cathodic Protection for Water Works Plants."—Electro Rust-Proofing Corp.

34*R*

Carbonation—A handbook on carbonation of lime softened waters. Includes discussion of the background, chemical reactions, methods and problems in carbonation. Corrosion, due to impurities in CO_2 produced by certain methods, is thoroughly covered with tables giving corrosion resistance of various metals.—Walker Process Equipment, Inc.

35*R*

Celite Filtration—A 12-page brochure describing and illustrating the advantages of Celite diaomite filter aids in producing clear, pure potable water, controlling process water clarity, and removing harmful impurities from plant waste.—Johns-Manville Corp.

36*R*

Centrifugal Blowers—This bulletin contains illustrations, performance characteristics and specifications of this manufacturers complete line of single stage and multistage centrifugal blowers and exhausters. Typical installation applications are also included.—Roots-Connersville Blower.

37*R*

Centrifugal Pumps—This 20-page bulletin describes monobloc, single and two stage, centrifugal pumps in sizes ¾ to 6 inches. Drawings and rating curves are also included.—Worthington Corp.

38*R*

Chemical Feeders—This catalog pictures and describes electric vibrating feeders for the feeding of dry chemicals for water and sewage treatment plants.—Jeffrey Mfg. Co.

39*R*

Chemical Feeders—Bulletin 30-H12A on gravimetric loss-in-weight feeders; Bulletin 35-G5A on belt gravimetric feeders; Bulletins 20-P2 and 50-K5B on volumetric feeders; all for adding chemicals for water or waste-treatment—Omega Machine Co.

40*R*

Chemical Feeders—This bulletin describes positive displacement pumps for feeding corrosive fluids.—Omega Machine Co.

41*R*

Chemical Feeders—Publ. No. TP. 39M-4 describes dry chemical feeders of volumetric type.—Wallace & Tiernan, Inc.

42*R*

Chemical Treatment—Bulletin A-705 discusses the use of chemicals in water and sewage treatment.—Columbia-Southern Chemical Corp.

43*R*

Chlorine—A bulletin describing the physical properties, handling methods, uses and containers.—Penn Salt Mfg. Co.

44*R*

Chlorine—Bulletin containing general information on the properties, containers, and handling of liquid chlorine.—Pennsalt Chemical Corp.

45*R*

Chlorine—General information, prices, list of local distributors, shipping containers and liquid chlorine, calcium hypochlorite, and sodium hypochlorite.—John Wiley Jones Co.

46*R*

Chlorine Dioxide—A booklet discussing in detail the removal of tastes and odors by chlorine dioxide treatment and its bactericidal properties, methods of treatment and application. Economic factors and general installation instructions are also included.—Industrial Chemical Div., Olin-Mathieson Chemical Corp.

47*R*

Chlorine Feeders—A series of bulletins on Chlorinizers, for feeding chlorine gas and other gases like ammonia, sulfur dioxide, etc. Capacities from 4 to 8000 lbs. per 24 hours.—Builders-Providence, Inc.

48*R*

Chlorine Feeders—Bulletins on chlorinators particularly for swimming pools. —Chemical Equipment Co.

49*R*

Chlorine Feeders—A series of bulletins covering "Sterelators" both portable, wall, and large capacity models.—Everson Mfg. Corp.

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50*R*

Chlorine Feeders—A series of catalogs on chlorinators and accessory equipment, ranging in application from swimming pools to high capacity industrial requirements.—Fischer & Porter Co.

51*R*

Chlorine Feeders—Bulletin on V-Notch variable orifice chlorinator.—Wallace & Tiernan, Inc.

52*R*

Chlorine Feeders—Cat. File Nos. 20,100, 50, 110, present mechanical diaphragm vacuum type solution feeder and chlorine flow recorder.—Wallace & Tiernan, Inc.

53*R*

Chlorine Handling—Bulletin A-505 discusses the problem of the Safe Handling of Chlorine.—Columbia-Southern Chemical Corp.

54*R*

Chlorine Residual Recorder—Catalog 50.250 describes the WT Residual Chlorint Recorder as an instrument for measuring residual chlorine amperometically in a continuous sample and recording the reading in parts per million on a 24 hour circular chart. Advantages, case histories, design features, operation and technical data are included.—Wallace & Tiernan, Inc.

55*R*

Chlorine Wall Chart—Chart describes container valves, leak detection, first aid and accident procedure.—Penn Salt Mfg. Co.

56*R*

Chlorine Wall Chart—This chlorine wall chart lists some of the important things to do in handling liquid chlorine in cylinders, ton containers and tank cars. It covers first aid and emergency procedures. The chart is clearly illustrated with diagrams of chlorine container valves.—Hooker Electrochemical Co.

57*R*

Clamps and Saddles for Pipe Repair—Catalog GW gives complete description and specifications on all Skinner seal clamps and saddles. Also serves as a pipe repair manual.—M. B. Skinner Co.

58*R*

Clarifiers—This bulletin describes two settling type clarifiers for both circular and rectangular tanks, equipped with both skimming and sludge scraping machanisms.—Hardinge Company, Incorporated.

59*R*

Clarifier Mechanisms—This bulletin describes the conventional center drive type clarifier mechanisms, and, rectangular, drag-line sludge collectors, and the "Streamline".—Yeomans Brothers Co.

60*R*

Clarifiers, Spiraflo—This 8-page catalog covers the exclusive features of this settling tank for either primary or final tank installations.—Yeomans Brothers Co.

61*R*

Clariflocculator—This bulletin describes the physical characteristics, principle of operation, types, sizes and advantages of this combination flocculation and clarification mechanism. Included are photographs of operating installations and line and wash drawings of standard units.—Dorr-Oliver Inc.

62*R*

Clean Swimming Pools—This circular gives helpful information on the treatment of swimming pool water and describes Taylor equipment for chlorine and pH testing.—W. A. Taylor & Co.

63*R*

Coal and Ash Handling—Two folders and a catalog on coal and ash handling layouts; also a catalog on chains, and a series of questions and answers on ash handling.—Beaumont-Birch Co.

64*R*

Comminutor—Bulletin 185-D presents complete data, details and installation information on the company's comminutor.—Chicago Pump Co.

65*R*

Comminuting Devices—Bulletins 5100 and 5150 discuss the "Griductor" and "Rotagrator" screens and comminutors with many illustrations of design principles.—Infilco Incorporated.

66*R*

Concrete Pressure Sewer Pipe—A folder discussing features and standards of concrete pressure sewer pipe.—Price Brothers Co.

67*R*

Concrete Pressure Water Pipe—A booklet explaining and illustrating the proper method of laying concrete pressure pipe. The steps discussed are: digging the trench; checking grade; handling the pipe; lubricating joint rings; making the joint; checking the gasket; grade and line changes; completing the joint; bedding the pipe; and the use of pull jacks.—Price Brothers Co.

68*R*

Concrete Tanks—Bulletin of technical information on the design, construction and uses of prestressed concrete tanks. —Preload Co. Inc.

69*R*

Construction Tools—Illustrated 16 page catalog on rack drills; wagon drills; pavement breakers; clay spades; trench diggers; backfill tampers; drill steels; rock bits; air hose; and couplings.—Schramm, Inc.

70*R*

Contraflo Clarifier—A twelve page bulletin of information on clarification and water softening by the upward flow sludge blanket method. Suitable for boiler feed, cooling systems, paper manufacture, textile industry, chemical plants, and many other similar applications.—General Filter Co.

71*R*

Control Drives—Product specification P81-1 describes piston-operated power positioning drives for butterfly valves and other final control elements.—Bailey Meter Co.

72*R*

Control System Instruments—Bulletin 7202 describes miniature instruments for pneumatic transmission and control for water filtration plants.—Minneapolis-Honeywell Regulator Co.

73*R*

Controllers—Catalog includes detailed specifications and control action descriptions and ratings for both electric and pneumatic controllers.—Minneapolis-Honeywell Regulator Co.

74*R*

Controllers—Catalog 900 and 950 include detailed specifications and control action descriptions for both mechanical and pneumatic controllers.—Simplex Valve & Meter Co.

75*R*

Copper Sulphate—Two booklets on the use of Copper sulphate. "Copper sulphate in control of Microscopic Organisms", and "Copper sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains."—Phelps Dodge Refining Corp.

76*R*

Copper Sulphate—A 13-page booklet describing the use and application of sulphate in water treatment and algae control, and containing charts of chemicals required for various treatments.—Tennessee Corp.

77*R*

Corey Hydrant—This bulletin illustrated and describes the Rensselaer Corey hydrant.—Ludlow Valve Mfg. Co., Inc.

78*R*

Corrosion Control—A booklet on the description and the uses of Pitt Chem Tarset, a new coal tar-Epoxy resin coating for control of severe corrosive conditions.—Pittsburgh Coke & Chemical Co.

79*R*

Couplings, Asbestos-Cement Pipe—Features and installation on instructions for the use of Century "Fluid-Tite" couplings are graphically presented along with a chart of standard sizes.—Keasbey & Mattison Co.

80*R*

D. C. Motors—This bulletin describes direct-current motors, ½ through 200 hp, and motor-generator sets up through 200-kw output.—Allis-Chalmers Mfg. Co.

81*R*

Defoamant—Technical data sheet provides information on Foamwilt, an effective all-weather defoamant. Desirable characteristics and test results from various sewage plants are given, along with physical and chemical properties. —Fine Organics, Inc.

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82*R*
Demineralizers—Bulletin WC-111 discoutines the principles of demineralization by ion exchange. Give details of equipment arrangement, characteristics of ion exchange resins, equipment and resin specifications.—The Permutit Co.

83*R*
Demineralizers—Bulletin WC-111 discusses the design, theory, and equipment of ion exchange systems in detail. A cost estimating curve, system selection chart and other features are also included.—Graver Water Conditioning Co.

84*R*
Densludge Digestion System—A 16-page bulletin describes the development, equipment, operation, typical applications and design loading of this new sewage sludge digestion system and the means by which digester capacity requirements are substantially reduced.—Dorr-Oliver Inc.

85*R*
Deodorants—A paper and two folders discuss the effective reduction of sewage and waste odors and the science of Osmics.—Airkem, Inc.

86*R*
Deodorants—Technical literature on Cifon N. Y. and Arodon used as deodorants in sewage disposal plants.—Fine Organics Inc.

87*R*
Diatomite Filters—Design, features and advantages of diatomaceous earth filtration are discussed in this bulletin. Sizing table and typical specifications are included.—Graver Water Conditioning Co.

88*R*
Diatomite Filters—Bulletin 1800-3 on diatomaceous earth filters.—Proportioneers, Inc.

89*R*
Diffusion Plates & Tubes—This booklet describes fully porous ceramic-bonded plates and tubes for both air and gas diffusion. Also covered is their application to the activated sludge process and to other processes requiring uniform bubble diffusion.—The Carborundum Co.

90*R*
Digester Cover Roofing—A new concept in roofing for digester floating covers is described in bulletin 333. This roofing is said to provide longer life with better insulation and minimum maintenance.—Pacific Flush Tank Co.

91*R*
Digestion Equipment—This bulletin describes in detail advantages, design, construction and operation information on Chicago Pump's Catalytic Reduction Process for accelerated sludge digestion. —Chicago Pump Co.

92*R*
Double Suction Pumps—This bulletin describes and illustrates type M horizontally split case double suction pumps. —C. H. Wheeler Mfg. Co., Economy Pump Div.

93*R*
Dry Chemical Feeders—Bulletin 217 describes the operating principles and design characteristics of Type E dry chemical feeders. Bulletin 250 discusses lime mixers and feeders in which mixing is accomplished by agitators revolving in the vertical plane to prevent stratification.—Infilco Incorporated.

94*R*
Effluent Sampler—Bulletin describes the sampler and gives operating instructions. —Phipps & Bird, Inc.

95*R*
Electrical Control Panels—This bulletin describes typical custom electrical control panels for sewage lift stations, water and sewage plants.—Smith & Loveless, Inc.

96*R*
Electric Motors—This bulletin contains the line of U. S. Motors. Descriptions and full-color illustrations are included of open-type Uniclosed designs, totally-enclosed and explosion-proof types, Varidrives, Syncrogears, and right-angle worm gear models; also vertical motors and Verticlosed hollowshaft types.—U. S. Electrical Motors, Inc.

97*R*
Elevated Steel Tanks—A 24-page booklet discusses Horton Elevated Steel Tanks of Large Capacity and describes the advantages of using large elevated steel tanks to provide gravity pressure. It also contains, detailed information on the design and construction of the tanks and 12 photographs of actual installations, a table of sizes, and page of drawings showing construction details.—Chicago Bridge & Iron Co.

98*R*
Elevated Steel Tanks—This 20-page booklet includes dimensional data and capacities for 6 basic tank types, in addition to many installation photographs and descriptions. A cut-away view shows such accessory equipment for these tanks such as swivel ladder, stub overflow, steel balcony and vent.—Pittsburgh-Des Moines Steel Co.

99*R*
Elevated Storage Tanks—A brochure, "Cole Shallow Depth Steel Tanks" gives photographs and description, table of capacities and sizes of hemispherical, self-supporting bottom tanks.—R. D. Cole Manufacturing Co.

100*R*
Elevated Storage Tanks—Tables and photographs of standard Nooter water storage reserviors, standpipes and elevated tanks —Nooter Corp.

101*R*
Elevated Water Tanks—A 16-page brochure describing the Watersphere and Waterspheriod. These modern structures are used in municipal and private water systems to provide gravity pressure for general service and fire protection, and this use is described in the booklet. A portion of the booklet illustrates the "skyline advertising" use of these structures.—Chicago Bridge & Iron Co.

102*R*
Engines—A series of 4 bulletins describing Climax 4, 6, 8 and 12 cylinder gas engines in a range of sizes up to 600 hp. These engines are capable of operation on natural gas, butane, sewage gas, gasoline or a combination of any two of these fuels.—Climax Engine Manufacturing Co.

103*R*
Engines, Sewage Plant—A 20-page bulletin showing dual fuel engines, diesel engines and spark ignition engines. Contains engine selection chart, comparison fuel gas analysis chart and others.—Worthington Corp.

104*R*
Ferric Chloride, Anhydrous—A general information bulletin on the use of anhydrous ferric chloride in sewage and water treatment.—Pennsalt Chemical Corp.

105*R*
Ferric-Floc—A 38-page booklet describing the use and application of ferric sulphate in all phases of coagulation—Tennessee Corp.

106*R*
Filters—General information on Roberts filters for municipal water purifications, industrial water rectification, swimming pool recircuating systems and pressure filters.—Roberts Filter Mfg. Co.

107*R*
Filter, Automatic Backwash—Bulletin 46-A illustrates and describes how this automatic backwash sand filter traveling carriage cleans the compartmented filter bed section by section without interrupting the normal filtering operation.—Hardinge Company, Incorporated.

108*R*
Filter, Automatic Valveless—This bulletin describes the completely automatic gravity sand filter that uses no valves, pumps or flow controllers.—The Permutit Co.

109*R*
Filters, Diatomite—Diatomite Filters are being used more and more for swimming pool installations and for many industrial uses. This bulletin details the operation and shows a typical swimming pool installation.—General Filter Co.

110*R*
Filter Media—Bulletin on "Anthrafilt" tells the reasons why selected, graded, crushed anthracite is superior to sand as a filtering material.—Anthracite Equipment Corp.

111*R*
Filter Membrane—Illustrated booklet reviews approximately 80 technical articles reporting application of this analytical screening device in the study of gaseous and liquid suspended par-

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ticles in the sub-micron range size.—Millipore Filter Corp.

112*R*

Filters, Multi-Cell—Pressure filters are used in many treatment plants and this bulletin outlines advantages of the Multi-Cell method and gives various methods of backwashing.—General Filter Co.

113*R*

Filter Operating Panels—A product specification sheet and drawing discussing steel control panels for rapid sand filter operation. Each panel features inclined surface for optimum readability of the instruments and efficient operation of hand-automatic selector stations. —Bailey Meter Co.

114*R*

Filters, Pressure—Bulletin 2225 describes the operation and design features of pressure filters, both vertical and horizontal. Contains details of auxiliary equipment including Permutit Multiport Valve, also installation photos and specifications.—The Permutit Co.

115*R*

Filter Underdrains—Brochure gives complete information on "Criscrete" filter underdrains.—M C G Company.

116*R*

Filter Underdrains, Sewage—Bulletin UF-3 provides complete information on the Natco Unifilter Block Underdrains for trickling filter beds of sewage disposal plants.—Natco Corp.

117*R*

Fire Hydrants—This bulletin describes the Corey-type fire hydrants and Iowa waterworks valves.—Iowa Valve Co.

118*R*

Fire Hydrants—This 18-page catalog illustrates and describes the Ludlow slide gate type of hydrant.—Ludlow Valve Manufacturing Co., Inc.

119*R*

Fire Hydrants—This bulletin illustrates and describes the complete line of compression type fire hydrants made by the company.—A. P. Smith Mfg. Co.

120*R*

Fire Hydrants—Literature on Mathews modernized, Mathews flanged barrel and R. D. Wood swivel joint fire hydrants conforming to latest AWWA specifications and of designs to meet any requirement.—R. D. Wood Co.

121*R*

Flexible Pipe Couplings—This 44-page catalog contains complete descriptive material, illustrations and engineering data on flexible couplings for joining pipe from 3/8 to 72 inches and up in size. Hundreds of applications are listed and illustrated. It also includes information on Dresser's complete line of pipe fittings, pipe repair clamps and sleeves, service saddles, expansion joints etc.—Dresser Manufacturing Div.

122*R*

Floating Covers—This brochure gives design application data on positive, nontipping construction of Chicago-Wiggins Pontoon Digester Floating Covers.—Chicago Pump Co.

123*R*

Floating Covers—A bulletin that covers in 40 pages the theory of control digestion with digester design considerations, digester operation and floating cover construction details.—Pacific Flush Tank Co.

124*R*

Float-Treat System—For water, sewage and wastes treatment. Bulletin describes in detail the process in which suspended organic matter and usual chemical flocs are removed from process liquids by floatation.—Chain Belt Co.

125*R*

Flotation—This bulletin discusses the Graver "Aeroflotor" and shows the design features. The various uses and advantages of flotation are discussed.—Graver Water Conditioning Co.

126*R*

Flocculation—This catalog described the Flocrol process. Drawings, photos and dimensions are included.—Jeffrey Mfg. Co.

127*R*

Flocculation—Bulletins 2W66 and 2W72 cover impeller type and reel type flocculation units and rapid mixers for water and waste treatment.—Walker Process Equipment, Inc.

128*R*

Flocculation Equipment.—An 8-page booklet, "Equipment For Chemical Flocculation" illustrates and discusses Link-Belts line of conveyors and elevators for handling chemicals and flash and straightline mixers.—Link-Belt Co.

129*R*

Flocculation Equipment—This bulletin covers the pretreatment of water. Rex Flocrol design and arrangement are covered in detail. Information on Rex Slo-Mixers and Rex Flash-Mixers is included.—Chain Belt Co.

130*R*

Flocculators—Bulletin 6971 contains a description of Dorr-Oliver equipment used to perform the two basic steps of flash mixing and flocculation.—Dorr-Oliver Inc.

131*R*

Floor Grating—A bulletin discussing riveted, pressure locked, and all welded types of floor grating. General instruction for ordering and charts on safe loads are given. Borden safety steps are also discussed.—Borden Metal Products Co.

132*R*

Flow Measurement—Bulletin 115-L1A on Dall Flow Tube; Bulletins 110-N1 on Venturi Tubes; 135-F2A Kennison Nozzles; and 380-K4A on Propeloflo meters.—Builders-Providence, Inc.

133*R*

Flow Measurement—Bulletins 402, 500, 700, 750, and 950 cover equipment manufactured by the company for fluid flow measurement.—Simplex Valve & Meter Co.

134*R*

Flow Tubes—The Gentile Flow Tube, used for metering water, air, slurry, raw sewage sludge, paper stock, etc. Advantages of the flow tube are given, along with a performance table, head loss and differential charts. Photographs of actual installations and cut-away drawings are included.—Foster Engineering Co.

135*R*

Fluoride Feeders—This bulletin describes the Omega Fluoridizer for accurate continuous volumetric feeding of fluoride compounds.—Omega Machine Co.

136*R*

Gard Distributor—The Gard distributor for trickling filters is a nonseal, gravity actuated, rotary distributor that offers a number of major improvements which result in a more rugged, less sensitive and easier to maintain rotary distributor. —General Filter Co.

137*R*

Gas Safety Equipment—This bulletin provides capacity curves along with detailed drawings of a complete line of gas safety equipment designed expressly for sewage sludge gas. The bulletin also pictures a number of typical installations and provides a standard layout of a digester gas piping system.—Pacific Flush Tank Co.

138*R*

Gate Valves—This 36-page bulletin illustrates and describes AWWA gate valves, high and low pressure valves, as miscellaneous waterworks appurtenances. —Ludlow Valve Manufacturing Co., Inc.

139*R*

Gate Valve, AWWA—This bulletin illustrates and describes list 13A, AWWA Rensselaer gate valve as well as high and low pressure valves.—Ludlow Valve Mfg. Co. Inc.

140*R*

Generators—This booklet has specifications of gasoline-engine-driven AC generators along with descriptions of Homelite's full line of carryable construction equipment.—Homelite, Div. of Textron Inc.

141*R*

Gratings—Booklet discusses in detail the construction, design and load capacity of corrosion resistant aluminum gratings. Also contains information on aluminum stair and ladder treads.—Washington Aluminum Co.

142*R*

Gratings, Drainage—This literature lists many sizes, types and thicknesses in tabular form to help make a selection from numerous patterns—Clarksville Foundry & Machine Works.

Use Accompanying Reply Card to Obtain Copies of these Bulletins.

143*R*
Grinders—Complete data on grinders for sewage screenings is given in this catalog. It also covers sludge collectors and screens.—Jeffrey Mfg. Co.

144*R*
Grit Collectors—The 5 basic types of Rex grit collectors, making a broad comprehensive line, are covered in this bulletin.—Chain Belt Co.

145*R*
Grit Removal—This bulletin and technical supplement describe the grit conveyor, grit hydrowash, grit elevator and "American" Camp regulator for grit removal by velocity regulation and mechanical means.—American Well Works.

146*R*
Gunite—This 48-page booklet illustrates Gunite for repair and restoration to all existing concrete and masonry structures. Typical specifications are listed.—Pressure Concrete Co.

147*R*
Heat Exchanger—This brochure illustrates and describes the Cyclotherm Digester heater and heat exchanger.—Chicago Pump Co.

148*R*
Heat Exchanger—Bulletin 6281 on the spiral heat exchanger, an external element of the spiral flow type for controlling digestion tank temperatures—Dorr-Oliver Inc.

149*R*
Heat Exchangers—A 28-page bulletin presents a consise explanation of effective digester heating, scum control and operation of the P. F. T. Sludge Heater. Bulletin includes a method of computing size of heater and heat exchangers and table with complete size and operating data.—Pacific Flush Tank Co.

150*R*
Heat Transfer—This brochure gives detailed information on Chicago-Selas heat transfer system for superior sludge heating service.—Chicago Pump Co.

151*R*
Hi-Cone Sludge System—Catalog 6660 details operating and performance data of the Hi-Cone system. Complete specifications and layout dimensions are also included.—Yeomans Brothers Co.

152*R*
Horizontal Compressors—This 24-page bulletin discusses single stage, 10-150 psi, 50-2000 cfm compressors. It also contains drawings and specifications.—Worthington Corp.

153*R*
Hydrants and Valves—A general bulletin covering a complete line of hydrants and valves.—Darling Valve & Mfg. Co.

154*R*
Hydrofluosilicic Acid—A brochure on Hydrofluosilicic acid and it's uses for fluoridation by municipalities.—International Minerals & Chemical Corp.

155*R*
Hypochlorination—This booklet discusses various chlorination practices with HTH in granular and tablet form. Eight tables pertaining to chlorination are included.—Industrial Chemicals Div., Olin Mathieson Chemical Corp.

156*R*
Hypochlorinator—A bulletin describing a Heavy Duty Midget Chlor-O-Feeder as an all purpose, positive displacement, diaphragm pump for fluids such as hypochlorite, pH correctives, and abrasive slurries. The midget delivers 0.5 to 9 gph against pressures up to 85 pisg.—Proportioneers Inc.

157*R*
Incinerators—This attractive bulletin describes and illustrates the C-E incinerator stoker for the incineration of municipal refuse.—Combustion Engineering, Inc.

158*R*
Incinerators—Bulletin 111C gives complete information on mechanically stoked incinerators for municipal use.—Morse-Boulger Destructor Co.

159*R*
Incinerators—Bulletin 182 presents incinerators for institutional and industrial wastes.—Morse-Boulger Destructor Co.

160*R*
Industrial Waste Treatment—Bulletin WC-116 discusses Graver's facilities to handle industrial waste treatment problems.—Graver Water Conditioning Co.

161*R*
Industrial Waste Treatment—Industrial thickeners for blast furnace flue dust washer water clarification, and similar applications are described.—Walker Process Equipment Inc.

162*R*
Instruments, Filter Plant—Bulletins 1001, 1002, and 1100 illustrate and describe filter plant gauges and summator equipment.—Simplex Valve & Meter Co.

163*R*
Instruments, Flow Measurement—General catalog 005 presents equipment on meters and gauges for flow measurement.—Simplex Valve & Meter Co.

164*R*
Instrumentation—Data sheets for instrumentation on water and sewage treatment plants; the different types of equipment used and their application.—Fischer & Porter Co.

165*R*
Instrumentation—A 16-page booklet covering Foxboro instruments manufactured for water and sewage works applications.—Foxboro Co.

166*R*
Insulation—Bulletin D-40 gives complete data on NoDrip tape, a cork-filled water resistant pipe covering that prevents "sweating" or condensation on cold lines.—J. W. Mortell Co.

167*R*
Iron Removal—A sixteen page booklet describing various methods of Iron Removal together with limitations, advantages and dis-advantages of various methods.—General Filter Co.

168*R*
Jointing Compound—A complete data book on Hydro-Tite, the self-caulking jointing compound for cast iron water mains.—Hydraulic Development Corp.

169*R*
Joint Cut-In Valves—Specifications, installation illustrations and explanatory text are included in this bulletin on mechanical joint cut-in valves and sleeves.—A. P. Smith Mfg. Co.

170*R*
Joints, Slip—Brochure on Crispin slip joints describing safe, fast way to remove and replace fixtures when repairing lines, etc.—Multiplex Manufacturing Co.

171*R*
Laboratory Instruments—Bulletins on Beckman Zeromatic and pocket pH meters, etc., and other laboratory instruments such as: UV-Visible and infrared spectrophotometers, and gas chromatographs.—Scientific Instruments Div., Beckman Instruments, Inc.

172*R*
Lime Slakers—Bulletin 40-E1B covers equipment for lime slaking at 175 to 10,000 lb. per hour with thermostatic water control and vapor removal devices.—Omega Machine Co.

173*R*
Liquid Feeders, Rotodip—Bulletin 65-H12B on a volumetric feeder for liquids, including acids, alkalies, or slurries at rates from 0 to 1800 gallons per hour with repeatable accuracy within ±1%.—Omega Machine Co.

174*R*
Maintenance of V-Belts—This bulletin contains simple precautions to be exercised to prolong the life of V-belts, to increase drive efficiency and thereby assure full continuous production.—Allis-Chalmers Mfg. Co.

175*R*
Manhole Rings & Covers—This literature describes and illustrates numerous sizes and types for heavy, light, or pedestrian traffic. Top or bottom flanges; cast iron steps.—Clarksville Foundry & Machine Works.

176*R*
Mechanical Joint—This bulletin illustrates and describes the Clow mechanical joint cast iron pipe.—James B. Clow & Sons, Inc.

177*R*
Mechanical Jointed Clay Pipe—A 4-page folder describes the new AMVIT jointed vitrified clay pipe, sizes 4 through 24 inches as a true "built-in" mechanical joint ready for immediate, quick and easy installation. The joint is furnished on all standard fittings, as well as pipe, permitting a bottle tight line.—American Vitrified Products Co.

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178*R*

Mechanical Joint Repair Sleeves—This bulletin describes mechanical joint repair sleeves for repairing cast iron and cement asbestos water main breaks.—Eddy Valve Co.

179*R*

Membrane Filter—Color illustrated booklet details the field and laboratory methods of bacteriological water analysis recently approved by the U.S.P.H.S.—Millipore Filter Corp.

180*R*

Meter Boxes—Literature illustrates and describes many sizes and types of cast iron meter boxes, and cast iron meter box rims and covers for concrete or tile settings.—Clarksville Foundry & Machine Works.

181*R*

Meter Repair—This complete, well illustrated 16-page manual for the water meter shop tells how to set up a repair and test program, how to lay out the shop, and step-by-step repair instructions.—Neptune Meter Co.

182*R*

Meter Setting and Testing—Catalog 56 contains complete listing of water meter setting and testing equipment along with information on good meter setting practice under various conditions.—Ford Meter Box Co. Inc.

183*R*

Meters, Sewage Gas—Bulletin C-5200 describes the company's entire line of sewage gas meters, both large and small capacities.—Rockwell Manufacturing Co.

184*R*

Meter Testing, Water—A 40-page book on methods and equipment for testing meters, including information on meter shop layout, meter performance, and a bibliography on meter maintenance.—Ford Meter Box Co., Inc.

185*R*

Meters, Water—Catalog gives full details of American disc type water meters, both frost bottom and solid casing types, sizes ⅝ to 6 inches.—Buffalo Meter Co.

186*R*

Meters, Water—This catalog gives details and specifications of Trident meters from ⅝ to 16" in size. Frost-proof and split-case meters for household use, style 3 meters for intermediate flows, and larger compound, crest and Protectus fire service meters are also covered—Neptune Meter Co.

187*R*

Meters, Water—Direct reading propeller type units for metering water and other free-flowing, non-corrosive liquids are described in this bulletin.—Omega Machine Co.

188*R*

Meters, Water—This bulletin describes and illustrates Rockwell's complete line of water meters for home and industry, including oscillating piston type, current meters and compound meters.—Rockwell Manufacturing Co.

189*R*

Microstraining—This folder presents test results and operating data on the removal of algae and suspended matter from water and from secondary sewage effluents.—Glenfield & Kennedy, Inc.

190*R*

Mixflo Pumps—A 16-page bulletin on mixflo pumps for irrigation, drainage, sewage disposal, condenser circulating and low head water supply. Performance curves and drawings are also included.—Worthington Corp.

191*R*

Modern Sewage Treatment—This 12-page bulletin describes the distinguishing characteristics, types, sizes, applications and operation of major Dorr-Oliver sewage treatment equipment and presents a number of typical plant flowsheets. Also included are photographs and line and wash drawings of various units.—Dorr-Oliver Inc.

192*R*

Monorake—This 12-page bulletin presents the Dorrco Monorake. It describes the design, types and sizes, operation and advantages of this mechanism for cleaning rectangular sedimentation basins and tabulates actual maintenance costs from a number of installations.—Dorr-Oliver Inc.

193*R*

Motors—Construction features of large end-shield bearing synchronous motors are described in this bulletin.—Allis-Chalmers Mfg. Co.

194*R*

Motors—The "Synduction" motor, a synchronous induction machine which provides dependable constant speed, simplicity of operation and low first cost in a variety of applications requiring 40 hp and below is described in this bulletin.—Allis-Chalmers Mfg. Co.

195*R*

Municipal Castings—Booklet showing manhole rings and covers, coal hole rings and covers, manhole steps, catch basins, valve boxes, drain pipe, and drainage or inlet grates, with or without frames.—Clarksville Foundry & Machine Works.

196*R*

Municipal Water Conditioning—This general bulletin discusses the various types of equipment available from the company to handle municipal water problems.—Graver Water Conditioning Co.

197*R*

Ovaloid Storage Tanks—A brochure, "Cole Ovaloid Tanks" gives photographs and table of capacities, size and necessary foundation space of full self-supporting bottom tanks with low head range.—R. D. Cole Manufacturing Co.

198*R*

Peri-Filter System—A bulletin on the Dorrco Aldrich Peri-Filter System comprised of a Dorr-Oliver pre-treatment unit and an annular rapid sand filter combined in a single unit. Economic advantages for either municipal or industrial users are discussed.—Dorr-Oliver Inc.

199*R*

pH and Chlorine Control—This handbook gives theory and applications of pH and chlorine control and describes the complete line of Taylor comparators for water and sewage analysis.—W. A. Taylor & Co.

200*R*

pH Control—This bulletin discusses the use of PH-Plus (½-lb. cakes of fused sodium carbonate) in pH control of swimming pool water and in general industrial water treatment. Covered in detail are various types of feeding equipment in which these slow-dissolving cakes of fused alkali will provide positive and economical alkalinity control.—Industrial Chemicals Div. Olin Mathieson Chemical Corp.

201*R*

pH Instruments—A series of three bulletins on portable pH meters and 12 bulletins on industrial pH meters provide complete information on the company's meters.—Beckman Instruments, Inc.

202*R*

Pipe Coatings—A 40-page booklet with pictures that describes the history and present use of pipe coatings.—Koppers Co. Inc.

203*R*

Pipe Cutter—A catalog sheet giving details on Models 6 and 12 pipe cutters for cutting cast iron, Duriron, vitreous clay water pipe and cement sewer tile. A parts and price list is also included.—Spring Load Manufacturing Corp.

204*R*

Pipe Cutting & Jointing Tools—A catalog sheet containing information on the Spring Load Machining and Tapering tool, for asbestos cement pipe. Catalog discusses machining pipe ends for: Ring-Tite couplings; simplex couplings; poured flange assembly; tapered couplings; making closures; and end facing.—Spring Load Manufacturing Corp.

205*R*

Pipe Tools—Catalog 39 discusses pipe cutters, pipe clamps and plugs, and accessory parts.—Ellis & Ford Mfg. Co.

206*R*

Pipe Laying & Jointing Tools & Equipment—A complete general catalog showing the line of equipment for water, sewer and gas lines.—Joseph G. Pollard Co., Inc.

207*R*

Pipe Locators—A brochure describing the new automation method of etched or 'printed' circuitry now employed in the Wilkinson Line Locator. Also, included is a description of new type selective antennas and long life phenolic material used in the instrument case.—Wilkinson Products Co.

208*R*

Pipe Locator—Descriptive brochure on pipe and leak locators.—Computer Measurements Corp.

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209R

Plastic Coatings—This 32-page handbook gives complete general and technical data on condensation and how NoDrip plastic coating controls it.—J. W. Mortell Co.

210R

Plastic Pipe—This catalog describes Van-Cor pipe, fittings and valves of unplasticized polyvinyl chloride. Full description of physical properties, chemical resistance and installation methods are included.—Colonial Plastics Mfg. Co.

211R

Pneumatic Operated Control—In the Water Plants POC is used for: (a) Measurement of—Loss of Head Through Filters, Filter Rate of Flow, Raw Water Rate of Flow, Backwash Rate of Flow, Treated Water Rate of Flow, Water Level in Treating Basins; (b) Control of—Filter Rate of Flow, Raw Water Rate of Flow, Chemical Feeds, Flow Blending (Ratio Control), Water Level under various uses—General Filter Co.

212R

Pneumatic Transmitter—Bulletin 285-L2B describes the BalanCel transmitter as a simple force-balance device for transmission of flow, level, and pressure data. Also for the summation, averaging, etc., of two quantities.—Builders-Providence, Inc.

213R

Pool Sanitation—42-page booklet discusses in detail the safe treating of swimming pool water with HTH. Describes the various methods and advantages of disinfecting water with calcium hypochlorite as opposed to other means of chlorination.—Industrial Chemicals Div., Olin Mathieson Chemical Corp.

214R

Porous Filter Bottoms—Porous plates and tubes, made from ceramic-bonded aluminum oxides, and their use in water filtration, softening and demineralization, diatomite filtration and direct liquid and gas filtration are described in this bulletin. Prepared especially for engineers and operating personnel.—The Carborundum Co.

215R

Porous Media—Bulletin describes use of porous ceramic plates and tubes in a wide variety of equipment used in the treatment of water, sewage and industrial wastes. Charts and tables help provide data required in operating units equipped with these porous media.—The Carborundum Co.

216R

Pressure Filters—This bulletin describes the company's line of horizontal and vertical sand and gravel pressure filters. Cut-away views and sizing tables are included.—Graver Water Conditioning Co.

217R

Pressure Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transits asbestos-cement Pressure Pipe, its manufacture, properties and advantages. The folder also shows how, in combination with the Ring-Tite coupling, makes possible installing water lines faster to last longer. Various installation photos are included.—Johns-Manville Corp.

218R

Prestressed Concrete—Bulletin gives case history of how prestressing saved time and materials in the construction of the Owl's Head sewage treatment plant in New York.—Preload Co., Inc.

219R

Proportioning Pump—Bulletin 1260-2 describes an automatic and proportioning chemical feeder, the Chem-O-Feeder which utilizes water from the main itself and which will feed disinfecting solution in proportion to variable flow in the main.—Proportioneers, Inc.

220R

Protective Coating—This data sheet describes Amercoat #88, designed to protect concrete, plaster, masonry from water penetration, staining, weather etc. —Amercoat Corp.

221R

Protective Coating—Twelve page folder containing illustrated descriptions of Bitumastic cold applied coatings, along with application data.—Koppers Co. Inc.

222R

Pumps—A series of 4 bulletins cover the complete line of "American" double-suction, split-case, single-stage, two-stage, end suction, axial flow, sludge and deep well turbine pumps.—American Well Works.

223R

Pumps, Centrifugal—Bulletin 1002 discusses single stage single and double suction centrifugal pumps with a capacity range of 50 to 600 gpm. Bulletin 1004 covers single stage double suction centrifugal pump with capacities of 1,000 to 20,000 gpm and heads to 350 feet. Two-stage horizontal pumps with capacities of 75 to 3,000 gpm and heads to 750 feet are covered in bulletin 1501-R.—De Laval Steam Turbine Co.

224R

Pump Controllers—This bulletin describes purged air and static pump controllers, and gives the different applications for each type. Controllers are suitable for both sewage and clear water. —Healy-Ruff Company.

225R

Pumps, Deep Well Vertical Turbine—This bulletin, in color, shows a cross-section of the Layne Vertical Turbine pump and application for it. Both the water and oil lubricated pump bulletins available.—Layne & Bowler, Inc.

226R

Pumps, Diaphragm Slurry—Bulletin KSP-1 describes the Komline-Sanderson 2 inch diaphragm slurry pump, a self-contained unit featuring dual ball-check valves and variable speed drive which permit gentle pumping action, positive feed and metering characteristics.—Komline-Sanderson Engineering Corp.

227R

Pumps, Freflo—A 12 page bulletin covering horizontal and vertical Freflo pumps for handling sewage and industrial wastes. It contains rating curves for 18 pump models. Also included are charts for selection of shafting for use with vertical pumps. Complete dimension data are given for all pump models. —Worthington Corp.

228R

Pump, Sanitation, Solids—This bulletin describes the Wemco Torque flow solids pump and presents three typical sanitation transfer problems. Included are tabulations of general specifications for each service.—Western Machinery Co.

229R

Pumps, Sewage and Sludge—The company has a series of bulletins giving data, design features, and specification information on sewage and sludge pumps.—Chicago Pump Co.

230R

Pump, Solids—This bulletin brings up-to-date dimensions and capacity information on the Wemco Torque Flow solids pump. A cutaway photographs and diagrammatic sketch illustrate the new pumping principle which eliminates clogging.—Western Machinery Co.

231R

Pumps, Submersible—A 12-page bulletin describes the line of BJ Submersibles and lists their advantages. Safety features, special applications, specifications and selection chart are included. A list of typical municipal and industrial uses are given along with a list of the sales and service offices.—Byron Jackson, Div. of Borg-Warner Corp.

232R

Rate Controllers—Bulletins 600-G6A and 600-J9A on filter effluent or back wash rate controllers.—Builders-Providence, Inc.

233R

Rate Recorder, Water Meters—This 4-page bulletin describes the Meter-Master as the "G-man" of the water works and lists several advantages offered. The bulletin shows how the unit can be attached to any meter, single or compound, and describes how on a compound installation it simultaneously records both sides of the meter on a single chart.—F. S. Brainard Co.

234R

Recarbonation—Bulletins 1300 and 1310 outline the story of recarbonation and its use in stabilizing lime-softened waters.—Infilco Incorporated.

235R

Receiver-Recorder—Specification sheets E12-5 and G91-9 covers the receiver recorder for pneumatic and electronic telemetering systems. This unit continuously records as many as four variables in any combination. Designed for plug-in receivers and controllers. Pneumatic connecting lines use Armortube Flexible, Protecting Pneumatic Cable.—Bailey Meter Co.

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236R

Regulators, Sewage Gas—This bulletin presents data on Rockwell's complete line of sewage gas regulators, with inlet pressures above and below 5 psi.—Rockwell Manufacturing Co.

237R

Ring-Type Fire Hydrants—This bulletin illustrates and describes the line of fire hydrants and gate valves with Ring-tite connecting joints made by the company.—A. P. Smith Mfg. Co.

238R

Rotary Sludge Dryers—This 4-page bulletin discusses and illustrates the Standard Hersey drying system for odor free sewage-sludge drying. Keyed photographs explain construction features.—Standard Steel Corp.

239R

Salt—This booklet illustrates the various types of salt available for use in the Zeolite water softening process.—Morton Salt Co.

240R

Samplers—This brochure illustrates and describes in detail the company's Tru-Test Sampler.—Chicago Pump Co.

241R

Samplers—This bulletin gives complete information on the construction and operation of the Trebler Sampler. The samplers are built for V-notched, rectangular and Cipoletti weirs, and for Parshall flumes.—Lakeside Engineering Corp.

242R

Screening Equipment—This technical bulletin describes mechanically cleaned bar screen and grinder designed for a wide range of channel widths and settings with grinder attached to sorting tray, returning shredded screenings to sewage flow.—American Well Works.

243R

Screening Equipment—Booklet 2587 illustrates and discusses Link-Belt's line of screening equipment for water, sewage and industrial waste. Dimension drawings and specifications are included.—Link-Belt Co.

244R

Self-Priming Pumps—Folder L-509 presents complete discriptions and specifications of self-priming, gasoline-engine driven, centrifugal and diaphragm pumps.—Homelite, Div. of Textron Inc.

245R

Sewage Ejector—A series of engineering tables provides a simplified method of selecting clog-proof "Flush Kleen" sewage ejectors. Examples are given for determining the inflow, discharge heads and type of ejectors to use.—Chicago Pump Co.

246R

Sewage Ejector System, Pneumatic—12-page, 2 color booklet describes the Blackburn-Smith Pneumatic Sewage Ejector that can be operated by either a mechanical float and electric float switch, a mechanical float and pneumatically controlled air valves, or electrode controls. Performance charts, photographs and installation diagrams are also included.—Blackburn-Smith Mfg. Co., Inc.

247R

Sewage Jointing—Three folders discuss and illustrate how unusual joint sealing problems were solved at different locations including 25-mile, 18-mile and 92-mile sewer projects.—Presstite-Keystone Engineering Products Co.

248R

Sewage Lift Stations—A 100-page Engineering Data Manual on factory-built sewage lift stations. Contains design notes, selection charts, drawings and specifications on stations of from 30 to 4500 GPM.—Smith & Loveless, Inc.

249R

Sewage Treatment—Bulletin 6041, Dorr-Oliver Equipment and Methods for Modern Sewage Treatment, describes briefly major components of Dorr-Oliver equipment available for primary through complete sewage treatment.—Dorr-Oliver Inc.

250R

Sewage Treatment—A 64-page catalog covering Jeffrey equipment for the treatment of sewage, water and industrial waste. It is profusely illustrated with installation views and line drawings.—The Jeffrey Mfg. Co.

251R

Sewage Treatment—A series of 6 bulletins gives detailed information on equipment to perform various steps in sewage treatment. Collectors for solids removal, screens, grit removal units, rotary distributors and digester sludge heating units are covered.—Walker Process Equipment Inc.

252R

Sewage And Waste Treatment—This brochure describes in detail Chicago Pump's Ratedaeration Sewage Treatment process for small flow requirements.—Chicago Pump Co.

253R

Sewage and Waste Treatment—Bulletin No. 300 is a general catalog of equipment and methods for modern waste treatment.—Pacific Flush Tank Co.

254R

Sewer Cleaning—This 48-page catalog describes the completely mechanical SeweRodeR for cleaning sewers at up to 3,000 or 4,000 feet per day with a 2-man crew. It describes how to remove sand, gravel, mud and rocks from main line sewers with a 3-man crew.—Flexible Inc.

255R

Sewer Linings, Plastic—This bulletin describes T-Lock Amer-Plate, a continuous plastic sewer lining to prevent hydrogen sulfide corrosion. It shows how the T-shaped ribs lock the sheet into the pipe when the concrete is poured.—Amercoat Corp.

256R

Sewer Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transite asbestos-cement sewer pipe, lists its advantages, and how it, with the Ring-Tite coupling makes possible tight sewer systems at low installation costs.—Johns-Manville Corp.

257R

Sewer Pipe, Clay—Catalog SE-50 gives a complete summary of shapes and sizes of clay sewer pipe and supplementary clay products.—Natco Corp.

258R

Single Stage Centrifugal Pumps—This 4-page bulletin discusses the single stage volute pumps for water works, circulation, drainage and general service.—Worthington Corp.

259R

Sewer Sealing System—"3 Steps to Tighter Sewer Joints" is a 20-page booklet on the Presstite Sealing System. The three steps, specifications, and actual installation photographs are also included. Presstite-Keystone Engineering Products Co.

260R

Sewer & Water Main Cleaning—This literature describes new, patented controlled power methods of cleaning water mains and sewers. Mobile units for mechanical cleaning of sewers and hydraulic or semi-hydraulic cleaning restores minimum of 95% capacity to clogged pipes.—National Power Rodding Corp.

261R

Silica (Activated) Feeder—Catalog 60.110 gives description, design features, operating instructions and technical information on the series A-637 WT Silactor, a device for the continuous production and application of chlorine activated silica.—Wallace & Tiernan, Inc.

262R

Silica Activator and Feeder—Bulletin 63-M1 describes equipment designed for the continuous activation and feeding of sodium silicate. The unit features sequence starting, automatic rinse, antigel interlock and variation of aging concentration and aging time.—Omega Machine Co.

263R

Sipons for Sand Filters—This bulletin provides curves for determining rates of siphons discharging into open troughs. Sand filter design for smaller plants is discussed along with piping layouts for the types of siphons available.—Pacific Flush Tank Co.

264R

Sludge Collectors—Bulletin 315-61 highlights Rex conveyor sludge collectors and appurtenances. Information is general in nature, and is intended primarily to illustrate the diversity and quality of these collectors.—Chain Belt Co.

265R

Sludge Digestion—Bulletin 6262 describe the Dorrco Densludge Process consisting of a grit washer, thickener, digester and spiral heat exchanger.—Dorr-Oliver Inc.

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266R

Sludge Digestion—Bulletin 6591 presents the Dorr type MA digester which incorporates, single stage digestion, high capacity mixing and gas storage in a single unit. Dorr-Oliver Inc.

267R

Sludge Digestion—Bulletin 35-D describes digester applied to sewage sludge in circular tanks.—Hardinge Company, Incorporated.

268R

Sludge Digestion—In addition to bulletins 332 and 235 on floating covers and sludge heat exchangers, P.F.T. has available bulletins 236 and 137 covering floating cover position indicators and gauge boards.—Pacific Flush Tank Co.

269R

Sludge Digestion Tanks—Bulletin on use of prestressed concrete in the construction of sludge digestion tanks.—Preload Co., Inc.

270R

Sludge Drying and Incineration—Bulletin FD-52 covers the C-E Raymond System of Sludge Drying and Incineration. It briefly outlines the problem of sewage disposal and shows why heat drying and incineration are regarded as an ideal solution. Digrams and photographs are also included.—Combustion Engineering Inc.

271R

Sludge Removal—Bulletin 253B describes "American" positive flight conveyors, circular clarifiers, and sludge control valves.—American Well Works.

272R

Sludge Removal—Rex Unitube Tow-Bro for removal of light, tricky sludges is covered in this bulletin. New, improved header design is introduced.—Chain Belt Co.

273R

Softener and Clarifier—The Reactivator, a high rate cold process softener and clarifier. Cut-away "how-it-works," drawing is also included.—Graver Water Conditioning Co.

274R

Spherical Storage Tanks—A Brochure, "Cole Spherical Tanks on Tubular Towers". Photographs of installations, table of capacities and sizes, of spherical steel tanks on tubular towers.—R. D. Cole Manufacturing Co.

275R

Spiragesters—Two bulletins describe the Spiragester, which is a combination clarifier and digester with no moving parts except for one small pump which operates once each hour for about five minutes.—Lakeside Engineering Corp.

276R

Square Bottom Valve—This bulletin gives complete descriptive information on the Rensselaer square bottom valve. —Ludlow Valve Mfg. Co., Inc.

277R

Squirrel-Cage Motors—This bulletin describes the company's large two-pole squirrel-cage induction motors, 900 hp and larger, designed to meet requirements of today's high speed drives.—Allis-Chalmers Mfg. Co.

278R

Standard Sewage Siphons—This bulletin describes the P.F.T. standard sewage siphon for small disposal plants for use with small sand filters, sub-surface tile fields and either septic tanks or small Imhoff tanks. Standard dimensions and capacity of siphons are included.—Pacific Flush Tank Co.

279R

Steam Cleaner—Booklet discusses the Hypressure Jenny steam cleaner for cleaning and deodorizing bar screens, grit and scum loading pits, etc.—Homestead Valve Mfg. Co.

280R

Steel and Alloy Structures—This 4-page folder outlines briefly the many services to industry provided by Graver-built steel and alloy structures, both smaller shop-built vessels and large field-erected installations.—Graver Tank & Mfg. Co., Inc.

281R

Steel Pipe—A series of four booklets illustrates and discusses the applications of steel pipe as a 14-ft. 8-in. diameter welded steel flow line, 42-in. diameter tar-enameled for water supply, a 72-in. force main and the fabrication of a 96-in. steel pipe and its installation.—Bethlehem Steel Co.

282R

Steel Pipe—Booklet 402 describes the construction of a 72-inch Ramapo force main for the North Jersey Water Commission. Booklet 408 covers the construction of a 37,000-ft. Northwest pumping main at Reading Pa. The Welded Steel Pipe booklet describes the fabrication of a 96-inch steel pipe and its installation at Sparrows Point, Md.—Bethlehem Steel Co.

283R

Steel Reservoirs and Standpipes—A 24-page booklet on Horton Steel Reservoirs and Standpipes. Illustrations show installations from 50,000 to 10,000,000 gal. capacity with cone, umbrella, or ellipsoidal roofs and ornamental structures with special architectural features. Also included are: table of standard capacities, information on foundations, advantage of pickling and painting, and data on the use of suction tank for fire protection.—Chicago Bridge & Iron Co.

284R

Steel Reservoirs and Standpipes—A brochure on flat bottom water storage that discusses the uses of steel tanks with photos showing various roof types, ornamental structural features, and various sizes. A list of standard reservoir dimensions is also included.—Pittsburgh-Des Moines Steel Co.

285R

Storage Tanks—This 20-page booklet covers the many uses of standard storage tanks. Cone roof tanks serving as storage units at innumerable industrial and municipal installations are shown.—Graver Tank & Mfg. Co., Inc.

286R

Supervisory Control—Bulletin AA-2 describes some of the applications of supervisory control for plant operations, provides illustrations of the various equipment used and gives a brief description of the method of operation for this automatic and remote control unit. —Control Corp.

287R

Supervisory and Remote Control—Bulletin 240-M6 describes unlimited number of control or advisory functions from central control panel over widely spread system using sequencing transmission system. Other bulletins describe Chronoflo telemetering, "Synchro-Scan" pneumatic and electrical transmission and control of level pressure, pumps, etc.—Builders Providence, Inc.

288R

Surge and Hammer Control—Bulletin 200 illustrates and describes the company's Controlled Closing air valve that was designed for the protection of pipe lines against surge built-up pressures or water hammer.—Simplex Valve & Meter Co.

289R

Surge & Water Hammer Control—A 28-page booklet describing construction and operation of Crispin valves available for automatic control of air problems in pipe line operations.—Multiplex Manufacturing Co.

290R

Swimming Pool Equipment—The bulletin describes various types of purification and recirculation equipment. Details of equipment design, pool sizes and general sizing tables for equipment and pools are included.—Graver Water Conditioning Co.

291R

Swimming Pool Chemicals—This catalog gives complete data, prices, descriptions and usage of chemicals for water treatment of swimming pools, lakes and reservoirs.—Modern Swimming Pool Co., Inc.

292R

Swimming Pool Equipment—This 52-page catalog, profusely illustrated, contains data, photographs and prices of every item needed to build a new pool, or to equip and maintain an existing pool.—Modern Swimming Pool Co., Inc.

293R

Swing-Type Check Valves—This bulletin illustrates and describes the Rensselaer swing type check valves and the clear way, quiet closing check valve.—Ludlow Valve Mfg. Co., Inc.

294R

Tapping Machines—The S-54 tapping drilling machine, in size range 2 to 12 inches inclusive are illustrated and described in this bulletin.—A. P. Smith Mfg. Co.

295R

Tapping Sleeves—This bulletin describes and illustrates the complete line of mechanical joint tapping sleeves and valves manufactured by the company. A. P. Smith Mfg. Co.

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296R

Tapping Sleeves—Bulletin D illustrates and describes Rensselaer tapping sleeves and valve.—Ludlow Valve Mfg. Co., Inc.

297R

Tapping Valves & Sleeves—This bulletin illustrates and describes Iowa tapping valves and sleeves, and repair sleeves for water mains.—Iowa Valve Co.

298R

Tapping Valves & Sleeves Under Pressure—This bulletin describes the Eddy tapping valves and sleeves, for tapping water mains under pressure.—Eddy Valve Co.

299R

Taste and Odor Control—This booklet describes the use of Aqua Nuchar activated carbon in water purification.—West Virginia Pulp & Paper Co.

300R

Telemetering—Bulletins on tone signaling equipment and remote control equipment for plant operations.—Hammarlund Mfg. Co., Inc.

301R

Telemetering—Transmission and reception of data on flow, liquid level, pressure, temperature, etc., from any distance over a single two-wire circuit is shown in this bulletin.—Builders-Providence, Inc.

302R

Thickeners—Bulletin 31-E describes the "Auto-Raise" thickener mechanism for both small and large heavy duty settling tank operations, and waste treatment applications of the rectangular type clarifier.—Haringe Company, Incorporated.

303R

T-Lock Amer-Plate—This brochure describes T-Lock Amer-Plate, a continuous plastic sewer lining. "T-Lock" refers to the T-shaped ribs which project from the back of the sheet and lock the sheet into the pipe or structure when the concrete is cast.—Amercoat Corporation.

304R

Trash Racks—Bulletin No. 158 describes the Leonard Trash Rack Rakes with dimensions, specifications, and typical arrangements.—S. Morgan Smith Co.

305R

Trenchers and Backfillers—A 2-color booklet describing the features and listing specifications of the models 92 and 95 "Baby Diggers," the models 110, 140, 240, and 320 standard trenchers, and models 80W and 190 backfillers. Photographs of each piece of equipment are shown along with illustrations of the equipment in operation.—Cleveland Trencher Co.

306R

Trenching & Construction Equipment—Thirteen bulletins on tractors, crawlers, trenchers and loaders for installation of water mains or sewers.—Oliver Corp.

307R

Trickling Filter Distributor—This technical bulletin describes reaction and positive drive types, equipped with patented dual oil seal which will withstand at least 10' of water pressure.—American Well Works .

308R

Trickling Filter Distributor—This bulletin describes the Dorrco Distributor, a self-propelled rotary unit for low and high rate trickling filters.—Dorr-Oliver Inc.

309R

Trickling Filter Distributor—This bulletin describes the "Sy-No-Seal" reaction type rotary distributor which contains no seal between the stationary center column and the rotating distribution arms.—Smith & Loveless, Inc.

310R

Trickling Filters Distributor—Bulletin 313A covers spreader jets for rotary distributors for trickling filters.—Pacific Flush Tank Co.

311R

Tyton Joint Pipe—This booklet presents the U. S. centrifugally cast "Tyton joint" pipe for water and sewage. This new joint pipe is simple, sturdy and tight. Illustrations show details of joint and method of assembly.—U. S. Pipe & Foundry Co.

312R

Upflow Clarifier—Bulletin 6W46 describes clariflow unit, a vertical rise clarification unit for circular, square and rectangular tanks.—Walker Process Equip. Inc.

313R

Upflow Coagulation Unit—This bulletin describes the operation, advantages and design features of the Permutit Precipitator and contains flow diagrams, installation photos and specifications.—The Permutit Co.

314R

Vacuum Filter—Latest information on the Coilfilter, a vacuum filter which features non-clogging permanent filter media to obtain constant output, low operating cost, and simplified operation. Standard sizes of equipment are listed. —Komline-Sanderson Engineering Corp.

135R

Valves—A folder discussing bronze and iron valves, gate, globe, angle, check and meter valves, sluice gates, pivot valves and motor unit.—Chapman Valve Manufacturing Co.

316R

Valves, Air—A 28-page catalog offering complete information on the many types of Crispin air valves.—Multiplex Manufacturing Co.

317R

Valves, Altitude and Level—Bulletin W-4-A describes altitude valves and modifications of water level control valves.—Golden-Anderson Valve Specialty Co.

318R

Valve Box Locator—This bulletin discusses and illustrates this small, rugged easy-to-use instrument, that operates without batteries, wires or switches, for locating water or gas valve boxes buried under earth, blacktop, ice or snow.—Aqua Survey & Instrument Co.

319R

Valves, Butterfly—This bulletin covers a new series of butterfly valves designed primarily for municipal water supply or disposal systems.—Allis-Chalmers Mfg. Co.

320R

Valves, Butterfly—Bulletin 650-L1B on tight-closing rubber seated butterfly valves built to AWWA specifications.—Builders-Providence, Inc.

321R

Valves, Butterfly—A manual on rubber seated butterfly valves containing complete information including data on valve sizing, operator selection, theory of valve design, etc.—Henry Pratt Co. Inc.

322R

Valve, Butterfly—This 2-color brochure describes Leopold rubber seated butterfly valves. Complete details on the construction features and valve assembly are included.—F. B. Leopold Co., Inc.

323R

Valves, Check—Bulletin #W-1 illustrates and describes cushioned type swing check valves.—Golden-Anderson Valve Specialty Co.

324R

Valve Controls and Gear Drives—A folder illustrating and discussing various gear motors and controls, including the LimiTorque valve controls. Catalogs numbers are given for complete information about each product.—Philadelphia Gear Works, Inc.

325R

Valves, Diaphragm—Folder gives complete information on the Grinnell-Saunders strightway diaphragm valve.—Grinnell Co. Inc.

326R

Valves, Gate—Manual, electric motor, and hydraulic cylinder operated gate valves, in sizes 2 to 66 inches, are illustrated and described in this bulletin. —A. P. Smith Mfg. Co.

327R

Valves and Hydrants—Circular 49 is a listing of a complete line of gate valves and hydrants with mechanical joint ends.—M & H Valve and Fittings Co.

328R

Valves & Hydrants—Catalog 52 describes and illustrates complete line of gate valves, hydrants, pipe fittings, and accessories for construction of water works systems, sewage plants, filter plants and industrial uses.—M & H Valve & Fittings Co.

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329R

Valves, Lubricated Plug—This bulletin describes and illustrates the utility of the Rockwell-Nordstrom lubricant-sealed plug valves in sewage treatment plants. —Rockwell Manufacturing Co.

330R

Valve and Meter Boxes—Bulletin 2000 on Valve, Roadway, Service and Meter Boxes along with Manhole Frames and Covers.—Alabama Pipe Co.

331R

Valves, Plug—This 36-page catalog contains the complete line of plug valves, discussing eccentric action and other exclusive features of the DeZurik valves. Sizes and other specifications are included.—DeZurik Corporation.

332R

Valves, Plug—This 18-page manual discusses the various lubricants for ACF plug valves. Amply illustrated with photographs and tables the manual gives descriptions of the lubricants, service recommendations and ordering instructions for the lubricants.—W-K-M Manufacturing Co., Inc.

333R

Valves, Plug—Book 38-2 describes cam-sealed quarter-turn plug valves. Book 39-3 shows lever-sealed quarter-turn plug valves with built-in means of moving plug under all conditions. Book 39-5 describes lubricated plug valves in straightway, 3-way, 4-way and multiple port types.—Homestead Valve Mfg. Co.

334R

V-Belts—Construction features of the "Texrope" grommet V-belt which provides 20 to 50 percent longer life than ordinary belts are described in this bulletin.—Allis-Chalmers Mfg. Co.

335R

V-Belt Drives—A 44-page booklet carrying handy multi-color tables for quick and easy selection of variable speed "Texrope" drives.—Allis-Chalmers Mfg. Co.

336R

Vertical Turbine Pumps—This bulletin, diagrammed in color, discusses water lubricated vertical turbine pumps in capacities of from 15 to 15,000 GPM.—Worthington Corp.

337R

Waste Treatment—Verti-Flo clarifier tanks are covered in two bulletins. Efficient, low cost Verti-Flo is designed to clarify plant water, reclaim process water, eliminate pollution, or reclaim valuable materials.—Chain Belt Co.

338R

Water Leak Locator—This bulletin describes this new listening device for locating water leaks in pipes.—Aqua Survey & Instrument Co.

339R

Water Main Cleaning—This catalog describes equipment for cleaning water mains of all sizes and in all conditions. Offers rodding equipment for hard deposits and short sections with sharp bends or pressure line scrapers, operated by water pressure for longer sections.—Flexible Inc.

340R

Water Conditioning Plant Package—This bulletin describes the operation of equipment which makes up the package water conditioning plant. This package plant is available in 8 standard sizes ranging from 500 to 3300 gph.—The Permutit Co.

341R

Water Screens—This bulletin fully describes traveling water screen designed for positive removal of floating debris and suspended matter from power station and water treatment plant influent. —The Jeffrey Mfg. Co.

342R

Water Storage Tanks—This single page offers in handy form the sizes and capacities available in the various water storage tanks offered by the company. Elevated water tanks, pump suction tanks, standpipes and reservoirs are listed.—Graver Tank & Mfg. Co., Inc.

343R

Water Treatment—Reference folder serves as a convenient file on the use of activated silica sol as coagulant aid for treating raw, process and waste waters. Advantages are cited and a list of metals protected are included.—Philadelphia Quartz Co.

344R

Water Treatment Equipment—A general descriptive brochure indicating the types of water treatment equipment available from the company.—Graver Water Conditioning Co.

345R

Water Treatment Plant—This fully illustrated 28-page bulletin covers the "Accelator" treatment plant.—Infilco Incorporated.

346R

Water & Waste—This bulletin offers 24-pages of illustrations and description covering the major equipment designed and manufactured by the company for water, waste and sewage treatment.—Walker Process Equipment Inc.

347R

Water and Waste-Water Treatment—Bulletin 35-D illustrates and describes equipment used for treatment of water, sewage and trade wastes.—Hardinge Company, Incorporated.

348R

Waterworks Products—This general bulletin describes miscellaneous Clow products, including cutting-in valves, water work sleeves, and other cast iron specials.—James B. Clow & Sons, Inc.

349R

Well Screens—General information, specifications and typical installations of Johnson Well Screens. Also available are sets of technical bulletins dealing with ground water problems such as corrosion and incrustation.—Edward E. Johnson, Inc.

350R

Well Strainers—A new 48-page catalog procedure for well strainer installation, slot well strainers, and contains information concerning the recommended procedure for well stainer installation, uses, etc.—Cook Well Strainer Co.

351R

Well Water Systems—Bulletin 100 illustrates and discusses pumps, drilling, allied services and equipment available from the company.—Layne & Bowler, Inc.

352R

Wound Rotor Motors—Construction features of the company's wound rotor motors for a variety of applications are described in this bulletin.—Allis-Chalmers Mfg. Co.

353R

Wrought Iron Installations—This 30-page technical bulletin describes the many applications for wrought iron products in sewage treatment and disposal plants, and cites specific installation in various parts of the country.—A. M. Byers Co.

354R

Wrought Iron Pipe—This 52-page manual contains more than 25 separate tables listing size and dimensional data of wrought iron pipe and tubular products. Other tables record dimensions of pipe in fractions of an inch, etc. Data is also provided about wire and sheet metal gages, flow of water in gpm and useful conversions factors.—A. M. Byers Co.

355R

Zeolite Water Softeners—This 20-page bulletin details the troubles caused by using hard water and the many economies effected by curing these troubles. The bulletin also contains equipment specifications, operating characteristics, and data on Permutit ion exchange resins.—The Permutit Co.

356R

Zeolite Water Softeners—This bulletin describes the zeolite exchange water softening process, includes details of equipment design and basic sizing tables. —Graver Water Conditionnig Co.

357R

Zinc Silicate Coating—This bulletin discusses and illustrated Dimecote #3, the 100% inorganic zinc silicate coating that provides near-permanent protection to steel exposed to severe conditions of rust, weathering and salt air, as well as fresh and salt water.—Amercoat Corp.

X. DIRECTORY OF MANUFACTURERS

ALL COMPANIES LISTED IN **BOLD FACE** TYPE HAVE ADVERTISEMENTS IN THIS ISSUE.

For the Index to the Reference and Data Material, and the Index to Advertisers, See the Rear Section of this Issue.

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Engines (Gas & Gasoline)
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Filter Equipment
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Pumping Controls
Pumps Acid Handling
Pumps Centrifugal
Pumps, Sewage & Drainage
Pumps, Sludge
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Joints, Mechanical, Flexible
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Pipe, Culvert
Pipe Test Plugs
Saddles, Pipe
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Valves, Mechanical Joint

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(Pitts. Plate Glass Co.)
420 Fort Pitt Blvd.
Pittsburgh 22, Pa.
Ammonia, Anhydrous & Aqua
Calcium Hypochlorite
Chlorine, Liquid
Deodorizing (Service, Equipment, Chemicals, etc.)
Insecticides
Soda Ash

Combustion Engineering, Inc.
200 Madison Ave.
New York, New York
Drying Systems (Sludge)
Incinerators

Computer-Measurements Corp.
5528 Vineland
North Hollywood, Calif.
Pipe Detector

Control Corporation
718 Central Ave.
Minneapolis, Minn.
Combustion Indicators, Recorders
Electrical Control Equipment
Gate Valve Operator
Rate of Flow Controllers
Rate of Flow Recorders
Regulators, Pressure, Water, Gas

Cook Well Strainer Co.
6330 Glenway Ave.
Cincinnati 11, Ohio
Screens, Water well

Crane Company
836 S. Michigan Ave.
Chicago 5, Illinois
Cocks, Curb, Meter, Corp, etc.
Couplings, and connections, Pipe
Fittings, Pipe, Solder Type
Gages, (Liquid Level, Pressure Recording)
Joints, Expansion, Pipe
Traps, Drip, Flame, Sediment, Steam
Valves, Diaphragm
Valves, Foot
Valves, Four Way
Valves, Gate
Valves, Hydraulic, Cylinder operated
Valves, Motor Operated
Valves, Pressure Reducing
Valves Relief
Valves, Rubber, Plastic, Glass or Lead

D

W. S. Darley & Co.
2810 Washington Blvd.
Chicago 12, Illinois
Furnaces, (Meltings, Pouring, Ladles, Pots, etc.)
Jointing Compounds and materials
Pipe Thawing, Electrical, Steel, Flame,
Pumps, Centrifugal
Pumps, Hydraulic
Pumps, Portable
Pumps, Self Priming,
Water, Leak, Locating Instruments

Darling Valve & Mfg. Co.
Walnut St.
Williamsport, Pa.
Valves, Air Relief
Valves, Diaphragm
Valves, Chlorine
Valves, Check
Valves, Air Realese and Vacuum Breaking
Valves, Motor Operated
Valves, Relief
Valves, Gate
Valves, Hydraulic, Cylinder operated
Valves, Mechanical Joint
Valves, (Rubber, Plastic, Glass, Lead)
Valves, Special Automatic including remote control
Sleeves, Tapping (Valve)

De Laval Steam Turbine Co.
Trenton, N. J.
Blowers, Air Gas
Compressors, Air
Couplings, Flexible
Drives, Right Angle Gear

Gears, Speed Reducing
Pumps, Centrifugal
Pumps, Hydraulic
Pumps, Acid Handling
Pumps, Rotary
Pumps, Self-Priming
Speed Reducers, Transmission
Turbines, Steam

De Zurik Corporation
49 Riverview Rd.
Sartell, Minnesota

Valve Boxes
Valves, Four Way
Valves, Gate
Valves, Hydraulic, Cylinder operated
Valves, Mechanical, Joint
Valves, Motor Operated
Valves, Mud and Plug
Valves, Sludge
Valves, Special Automatic including Remote control

Diamond Alkali Co.
300 Union Commerce Bldg.
Cleveland 14, Ohio

Acid Sulphuric and Hydrochloric
Chlorine, Liquid
Soda Ash
Sodium Silicate
Weed Killers

Dixie Tank & Bridge Co.
Box 14
Memphis 1, Tenn.

Tank, Maintenance and Repair

Dorr-Oliver Inc.
Barry Place
Stamford, Conn.

Aeration Apparatus
Agitators
Clarifiers, Sewage and Water
Coagulating Aids
De-Mineralization Equipment (Water)
Diatomite Filter Septums
Digester Equipment (Sludge)
Distributors (Sewage Filter)
Filter Equipment
Filters Vacuum
Flocculating Equipment
Gas Holders
Grinders, Garbage and Screenings
Grit Chamber Equipment and Grit Washers
Heaters, Digester
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Diaphragm
Pumps, Sewage and Drainage
Pumps, Sludge
Pumps, Vacuum
Screens, Sewage
Sludge Collectors
Sludge Disintegrators
Thickeners (Sludge)
Trickling Filter Equipment
Vacuum Filters
Water Softening Equipment

Dresser Manufacturing, Div.
Dresser Industries, Inc.
Bradford, Pa.

Clamps
Clamps, Ball Joint
Clamps, Pipe Repair
Joints, Expansion-Pipe
Joints, Mechanical Flexible
Pipe Joints (Mechanical)
Saddles, Pipe
Sleeves, Pipe Repair

E

Economy Pumps, Inc. Div.
C. H. Wheeler Mfg. Co.
19th & Lehigh Sts.
Philadelphia 32, Pa.

Pumps, Hydraulic (Pressure Boosting)
Pumps, Sewage and Drainage
Pumps, Sludge
Pumps, Sump and Cellar Drainers
Pumps, Vacuum

Eddy Valve Co.
Waterford, N. Y.

Gates, Shear
Valve Boxes
Valves, Air Relief
Valves, Flap
Valves, Float
Valves, Foot
Valves, Mechanical Joint
Valves, Mud and Plug
Valves, Relief

Electro Rust Proofing Corp.
1 Main Street
Belleville 9, New Jersey

Cathodic Protective Systems

Electric Machinery Mfg. Co.
800 Central Ave.
Minneapolis 13, Minn.

Alternators, Electric
Generators (Electric)
Motors, Electric
Switchboard & Switch Gear
Variable Speed Transmissions

Ellis & Ford Mfg. Co.
2425 Goodrich Ave.
Ferndale, Michigan

Pipe Cutting Machines

Everson Mfg. Co.
214 W. Huron St.
Chicago 10, Ill.

Ammoniators
Chemical Feeding and Proportioning Equipment
Chlorinators
Filter Equipment

F

Fairbanks Morse Co.
600 S. Michigan Ave.
Chicago 5, Illinois

Alternators, Electric
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines, Gas or Gasoline
Engines, Sludge, Gas
Generators, Electric
Stokers

Filtros, Inc.
East Rochester, N. Y.

Diffusers, Plates, Tubes, Fittings
Filter Underdrains, Water
Porous Tubes, Plates

Fine Organics Inc.
211 E. 19th St.
New York, N. Y.

Activated Carbon
Deodorizing

Fischer & Porter Co.
216 N. York Road
Willow Grove, Pa.

Ammoniators
Boiler Feedwater Treatment and Equipment
Chemical Feeding and Proportioning Equipment
Chlorinators
Combustion Indicators and Recorders
Controllers Flow, Level, Pressure, Temperature
Electrical Control Equipment
Filter Equipment
Flow Meters
Fluoridation Equipment
Gages (Liquid Level, Pressure Recording)
Gas Indicator and Detectors
Hypo-Chlorinators
Laboratory Apparatus Reagents and Equipment
Manometers
Meteorological Instruments
Meter, Flow Tube
Meters, Gas
Meter Testing Equipment
Meters, (Turbine Type)
Meters, Venturi
Orifices
Pumping Controls
Pumps, Acid-Handling
Pumps, Diaphragm
Rate of Flow Controllers
Rate of Flow Recorders
Regulators, Pressure (Water and Gas)
Valves, Chlorine
Valves, Diaphragm
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Motor Operated
Valves, Special, Automatic (Including Remote Control)
Venturi Tubes
Water Level Control
Water Level Recorders

Flexible Inc.
3786 Durango Ave.
Los Angeles 34, Calif.

Cleaning Water Mains
Pipe Test Plugs
Pipe Tools (Cutters, Extractors, Threaders, Wrenches, Etc.)
Sewer Cleaning Equipment and Service
Water Main Cleaning

Ford Meter Box Co., Inc.
PO Box 376
Wabash, Ind.

Meter Accessories-Boxes, Housing, Setting
Meter Couplings, Yokes
Meter Testing Equipment
Valve Boxes

Foster Engineering Co.
835 Lehigh Ave.
Union, New Jersey

Meters, Flow Tube

Foxboro Co.
298 Neposet Ave.
Foxboro, Mass.

Controllers-Flow, Level Pressure, Temperature,
Electrical Control Equipment
Meters, Flow Tube
Meters, Gas
Operating Tables (Filter)
Orifices
Pitot Tubes
Rate of Flow Controllers
Rate of Flow Recorders
Venturi Tubes
Water Level Controllers
Water Level Recorders

Frontier Chemical Co.
Div. of Union Chemical and Materials Corp.
Wichita, Kansas

Acid Sulfuric and Hydrochloric
Chlorine, Liquid

G

General Chemical Div.
Allied Chemical & Dye Corp.
40 Rector St.
New York 6, N. Y.

Acid Sulfuric and Hydrochloric
Activated Alum
Ammonia, Anhydrous and Aqua
Dechlorinating Equipment and Chemicals
Filter Alum
Insecticides
Laboratory Apparatus Reagents and Equipment
Sodium Phosphates (Glassy)
Sodium Silicate
Taste and Odor Removal Chemicals
Weed Killers
Well Cleaning Chemicals

General Filter Co.
923 2nd Street
Ames, Iowa

Agitators
Boiler Feedwater Treatment & Equipment
Carbonators (Recarbonation)
Chemical Feeding & Proportioning Equip.
Clarifiers, Sewage & Water
Controllers Flow, Level, Pressure, Temperature
De-Mineralization Equipment (Water)
Diatomite Filter Septums
Electrical Control Equipment
Filter Equipment
Filter Underdrains, Water
Flocculating Equipment
Gas Diffusers
Indicators, Large Dial Illuminated
Operating Tables (Filter)
Orifices
Rate of Flow Controllers
Rate of Flow Recorders
Sludge Collectors
Tank Linings
Trickling Filter Equipment
Water Softening Equipment
Water Treatment for Scale & Corrosion
Zeolite & Zeolite Softeners

Glenfield & Kennedy Inc.
706 North Ave.
New Rochelle, New York

Filter Equipment
Strainers-Suction

The Globe Co.-Grip Strut Div.
4026 S. Princeton Ave.
Chicago 9, Ill.

Gratings, Floorways, Treads

Golden-Anderson Valve Spec. Co.
1232 Ridge Ave.
Pittsburgh 33, Pa.

Valves, Altitude
Valves, Check
Valves, Cone
Valves, Float
Valves, Motor Operated
Valves, Pressure Reducing

Valves, Relief
Valves, Rubber, Plastic, Glass, Lead
Valves, Special automatic including Remote Control

Graver Water Conditioning Co.
216 W. 14th Street
New York 11, N. Y.

Activated Carbon
Aeration Apparatus
Agitators
Anthrafilt
Bins, Storage
Boiler Feedwater Treatment and Equipment
Carbonators (Recarbonating)
Chemical Feeding and Proportioning Equipment
Clarifiers, Sewage and Water
Dechlorinating Equipment and Chemicals
Demineralization Equipment (Water)
Diatomite Filter Septums
Feed Water Heaters
Filters
Filter Equipment
Filter Media
Filter Underdrains, Water
Flocculating Equipment
Grit Chamber Equipment and Grit Washers
Mixers and Mixing Equipment
Operating Tables
Sludge Collectors
Thickeners (Sludge)
Water Softening Equipment
Zeolite
Zeolite Softeners

Graver Tank & Mfg. Co.
4809 Tod Ave.
E. Chicago, Ind.

Clarifiers, Sewage & Water
De-Mineralization Equipment
Filter Equipment
Flocculation Equipment
Flotation Equipment
Mixers & Mixing Equipment
Tanks and Standpipes
Trickling Filter Equipment
Water Softening Equipment
Zeolite Softeners

Grinnell Co., Inc.
Providence, R. I.

Brass Goods
Fittings, Tees, Ells
Jointing Compounds, Materials
Joints, Mechanical, Flexible
Nozzles, Spray, Water and Sewage
Orifices
Pipe-Fittings, Lined
Sewer Pipe Joints & Jointing Compounds
Valves, Check
Valves, Chlorine
Valves, Diaphragm
Valves, Hydraulic (Cylinder operated)
Valves, Foot
Valves, Special Automatic (Including Remote Control)

H

Hagan Chemicals & Controls Inc.
Box 1346
Pittsburgh 30, Pa.

Gate Valve Operator
Rate of Flow Recorders

Hamilton Kent Mfg. Co.
427 W. Grant St.
Kent, Ohio

Coatings, Acid and Alkali-Proof
Couplings, Flexible
Joints, Mechanical Flexible
Rubber Packing Gaskets

Hammerlund Mfg. Co., Inc.
460 West 34th St.
New York 1, N. Y.

Electrical Control Equipment
Telemetering Equipment

Hardinge Co., Inc.
240 Arch Street
York, Pa.

Agitators
Castings, Iron, Steel, Alloy Steel
Clarifiers, Sewage and Water
Drying Systems (Sludge)
Filter Equipment
Flocculating Equipment
Sludge Collectors
Thickeners (Sludge)

Healy-Ruff Company
783 Hampden Ave.
St. Paul 4, Minn.

Alternators, Electric
Controllers Flow, Level, Pressure, Temperature
Electrical Control Equipment
Gages (Liquid Level, Pressure Recording)
Indicators, Large Dial Illuminated
Pumping Controls
Water Level Control

Hersey Mfg. Company
314 W. 2nd St.
South Boston, Mass.

Meter Repair Parts
Meters (Turbine Type)
Meter Testing Equipment
Meters, Water (Consumer)
Testers (Water Meter)
Valves, Check
Valves, Water Meter Special

Hollander Mfg. Co.
3841 Spring Grove Ave.
Cincinnati, Ohio

Gratings, Floorways, Treads, Railings

Homelite Corp.
Div. of U. S. Textron Inc.
67 Riverdale Ave.
Port Chester, N. Y.

Blowers Air, Gas
Engine-Generator Unit
Generators (Electric)
Pumps, Centrifugal
Pumps, Diaphragm
Pumps, Portable
Pumps, Self-Priming

Homestead Valve & Mfg. Co.
Box 348
Corapolis, Pa.

Cocks (Curb Meter, Corp. etc)
Valves, Cone
Valves, Four Way
Valves, Hydraulic Cylinder Operated
Valves, Lubricated Plug
Valves, Motor Operated
Valves, Mud and Plug

Hooker Electro Chemical Co.
Niagara Falls, New York

Chlorine, Liquid

Hydraulic Development Co.
50 Church St.
New York, N. Y.

Chains (Elevating, Conveying & Power Transmission)
Jointing Compound and Materials
Laboratory Apparatus Reagents and Equipment
Pipe Joint Tools
Sewer Pipe Joints (and Jointing Compounds)

I

Infilco Inc.
PO Box 5033
Tucson, Arizona

Activated Carbon
Aeration Apparatus
Agitators
Anthrafilt
Boiler Feedwater Treatment & Equipment
Chemical Feeding and Proportioning Equipment
Diatomite Filter Septums
Diffusers, Plates, Tubes, Fittings
Digester Equipment (Sludge)
Feed Water Heaters
Filters
Floating Covers (Digester)
Ferric Chloride
Filter Underdrains, Water
Filter, Media
Siphons, Sewage Dosing
Sludge Samplers
Stirrers
Taste & Odor Removing Chemicals
Trickling Filter Equipment
Valves, Four Way
Valves, Motor Operated
Valves, Special Automatic (Including Remote Control)
Venturi Tubes
Water Level Controls
Water Level Recorders
Water Softening Equipment
Water Treatment for Scale & Corrosion

Ingalls Iron Works
Birmingham, Ala.

Steel, Fabricating
Tanks & Standpipes

International Minerals, Inc.
20 N. Wacker Drive
Chicago, Ill.

Acid Sulfuric and Hydrochloric
Chlorine, Liquid
Fluoridation Chemicals

Iowa Valve Co.
201 W. Talman Ave.
Chicago, Ill.

Hydrants
Inserting Sleeves Valve
Meter Accessories, Boxes, Housing, Setting
Valve Boxes
Valves, Motor Operated
Valves, Mud & Plug

J

The Jeffrey Mfg. Co.
947 N. 4th St.
Columbus 16, Ohio

Aeration Apparatus
Agitators
Ash and Coal Handling Machinery
Bins, Storage
Castings, Iron, Steel, Alloy Steel, Etc.
Chains (Elevating, Conveying & Power Transmission)
Chemical, Conveying Equipment
Chemical Feeding & Proportioning Equipment
Clarifiers, Sewage & Water
Conveyors & Conveying Equipment
Couplings, Flexible
Digester Equipment (Sludge)
Flocculating Equipment
Grit Chamber Equipment & Grit Washers
Mixers & Mixing Equipment
Screens, Intake
Screens, Sewage
Screens, Vibrating
Sludge Collectors
Sludge Disintegrators
Sludge Samplers
Thickeners (Sludge)
Valves, Check
Valves, Gate

Johns-Manville Corp.
22 E. 40th St.
New York 16, N. Y.

Bituminous Coatings and Linings
Cements, Acid Proof and Alkali
Cements, Refractory
Cements, Sewer Pipe
Coatings, Acid and Alkali-Proof
Couplings, and Connections Pipe
Couplings, Flexible
Filter Aids
Filter Media
Forms and Gaskets for Pipe Joints
Gratings, Flooring, Treads, Railings
Insulation
Jointing, Compound and Materials
Joints, Expansion-Pipe
Packing (Pumps and Valves)
Pipe and Tank Coatings
Pipe, Asbestos-Cement
Pipe Joint Packing
Pipe, Sewer
Pipe Wrapping
Refractories
Roof Coatings
Rubber Packing Gaskets
Sewer Pipe Joints (and Jointing Compounds)
Stacks

Edward E. Johnson, Inc.
315 N. Pierce
St. Paul, Minn.

Diatomite Filter Septums
Filter Media
Screens, Water Well

John Wiley Jones Co.
Caledonia, N. Y.

Ammonia, Anhydrous & Aqua
Calcium Hypochlorite
Chlorine, Liquid
Taste & Odor Removal Chemicals

K

Keasbey & Mattison Co.
Ambler, Pa.

Jointing Compound Materials
Pipe, Asbestos, Cement
Pipe, Joint Packing

Klett Mfg. Co.
179 E. 87th St.
New York 28, N. Y.

Gates, Sluice
Laboratory Apparatus, Reagents, & Equipment
Turbidimeters

Komline-Sanderson Eng. Corp.
Peapack, New Jersey

Drying Systems (Sludge)
Filters, Vacuum

Pumps, Diaphragm
Pumps, Sludge

Koppers Company Inc.
Chamber of Commerce Bldg.
Pittsburgh, Pa.
Filter, Alum
Jointing Compound Materials
Paint, Acid Resistant
Pipe and Tank Coatings
Pipe Enamels-Protective, Coal Tar
Sewer Pipe Joint and Jointing Compound
Tank Linings

L

Lakeside Engineering Corp.
222 W. Adams St.
Chicago 6, Ill.
Aeration Apparatus
Boiler Feedwater Treatment & Equip.
Carbonators
Chemical Feeding and Proportioning Equip.
Clarifiers, Sewage & Water
De-Mineralization Equip.
Diatomite Filter Septums
Deodorizing
Distributors
Filter Underdrains, Water
Gates, Shear
Green Sand
Nozzles, Spray
Pumps, Sludge
Samplers
Sampling Tables
Sewage Samplers
Sludge Collectors
Thickeners
Trickling Filter Equip.
Valves, Float
Water Softening Equip.
Water Treatment for Scale & Corrosion
Zeolite
Zeolite Softeners

Layne & Bowler, Inc.
1993 Chelsea Ave.
Memphis, Tenn.
Contractors
De-Mineralization Equip.
Drilling & Boring Equip.
Filter Equipment
Pumps, Deep Well
Pumps, Sewage & Drainage
Pumps, Turbine
Water Softening Equipment
Well Cleaning Chemicals
Wells, Complete

Leopold & Stevens
4445 N. E. Glisan
Portland 13, Oregon
Controllers, Flow, Level, Pressure, Temperature
Flow Meters
Gages
Indicators, Large Dial Illuminated
Rate of Flow Recorders
Water Level Controllers
Water Level Recorders

F. B. Leopold Co., Inc.
227 S. Division St.
Zelienople, Pa.
Carbonators
Chemical Feeding & Proportioning Equip.
Contractors
Filter Equipment
Filter Underdrains, Water
Flocculating Equipment
Gate Valve Operator
Laboratory Apparatus, Reagents & Equipment
Operating Tables
Orifices
Samplers
Sampling Tables
Valves, Butterfly
Valves, Four Way
Venturi Tubes
Water Softening Equipment

Leroi Company
3716 W. Wisconsin Ave.
Milwaukee 14, Wisc.
Compressors, Air
Concrete Breakers
Engine Generator-Unit
Engines, Dual Fuel
Engines, Sludge Gas

Link Belt Co.
Prudential Plaza
Chicago 1, Ill.
Agitators
Ash & Coal Handling Mach.
Castings, Iron, Steel, Alloy Steel
Chemical Conveying Equip.
Clarifiers, Sewage & Water
Conveyors & Conveying Equipment
Couplings, Flexible
Flocculating Equip.

Lock Joint Pipe Co.
150 Rutledge Ave.
East Orange, N. J.
Concrete Pipe
Pipe, Concrete Pressure

Ludlow Valve Mfg. Co.
Ft. of Adams St.
Troy, N. Y.
Gates, Shear
Gates, Sluice
Gate Valve Operator
Hydrants
Inserting Sleeves, Valve
Sleeves, Tapping
Valve Boxes
Valves, Air Release & Vacuum Breaking
Valves, Butterfly
Valves, Check
Valves, Flap
Valves, Float
Valves, Foot
Valves, Four Way
Valves, Mud and Plug

M

M & H Valve & Fittings Co.
Anniston, Alabama
Hydrants
Inserting Sleeves Valve
Sleeves, Pipe Repair
Valves, Gate
Valves, Mechanical Joint
Valves, Motor Operated
Valves, Mud & Plug

M. C. G. Company
1851 Bedford Street
Columbus, Ohio
Filter Underdrains Water

W. R. Meadows, Inc.
16 Kimball Street
Elgin, Ill.
Waterstops

Millipore Filter Corp.
36 Pleasant St.
Watertown 72, Mass.
Filter Equipment
Laboratory Apparatus, Reagents & Equipment

Minneapolis-Honeywell Regulator Co.
Wayne & Windrin Aves.
Philadelphia 44, Pa.
Combustion Indicators & Recorders
Controllers, Flow, Level, Pressure, Temperature
Electrical Control Equipment
Gages (Liquid Level, Pressure, Recording)
Laboratory Apparatus, Reagents & Equipment
Meters, Electric
Meters, Flow Tube
Meters, Gas
Meters, Venturi
Operating Tables
Orifices
Pumping Controls
Rate of Flow Controllers
Sand Expansion Indicators
Valves, Butterfly
Valves, Diaphragm
Valves, Motor Operated
Valves, Pressure Reducing
Water Level Controllers
Water Level Recorders

Modern Swimming Pool, Inc.
1 Holland Ave.
White Plains, N. Y.
Chemical Feeding & Proportioning Equipment
Chlorinators
Chlorine, Liquid
Coagulating Aids
Drains, Gutter, Floor
Filter Aids
Water Softening Equipment

S. Morgan Smith Co.
York, Pa.
Valves, Altitude
Valves, Butterfly
Valves, Check
Valves, Cone
Valves, Diaphragm
Valves, Float
Valves, Hydraulic Cylinder Operated
Water Level Controllers

Morse Boulger Destructor Co.
80 Fifth Ave.
New York, N. Y.
Conveyors & Conveying Equipment
Drying Systems (Sludge)
Gates, Sluice
Incinerators (Sludge & Garbage)
Pumps, Diaphragm

J. W. Mortell Co.
580 Burch St.
Kankakee, Illinois
Coatings, Acid & Alkali Proof
Corrosion Suppression
Pipe & Tank Coatings
Tank Maintenance & Repair
Waterproofing, Paints, Compounds & Materials

Morton Salt Co.
120 S. LaSalle St.
Chicago 3, Ill.
Salt
Zeolite Water Softening

Mueller Co.
512 Cerro Gordo St.
Decatur 8, Ill.
Caulking Machines & Tools
Clamps & Sleeves, Pipe Clamps, Pipe Repair
Corrosion Suppression
Drilling & Boring Equipment
Fittings, Tees, Ells
Gates, Shear
Gates, Sluice
Gate Valve Operator
Hydrants (Fire)
Laboratory Apparatus, Reagents & Equipment
Lubricants, Valve
Meter Accessories, Boxes, Housing Setting
Meter Couplings, Yokes
Pipe, Copper, Brass, & Bronze
Pipe Joint Tools
Pipe Tapping Machines
Regulators, Pressure
Saddles, Pipe
Sleeves, Pipe Repair
Sleeves, Tapping
Valve Boxes
Valves, Check
Valves, Flap
Valves, Gate
Valve Inserting Machines
Valves, Mud & Plug
Valves, Pressure Reducing
Valves, Relief

Multiplex Mfg. Co.
Berwick, Pa.
Compressors, Air
Valves, Air Relief
Valves, Float
Valves, Relief

N

Natco Corp.
327 5th Ave.
Pittsburgh 22, Pa.
Bins, Storage
Filter Underdrains, Sewage
Pipe Sewer
Trickling Filter Equipment

National Clay Pipe Mfgrs. Inc.
1820 N. St. N. W.
Washington 6, D. C.
Filter Underdrains, Water
Pipe, Sewer

National Power Rodding Corp.
100 N. La Salle St.
Chicago 1, Ill.
Cleaning Water Mains
Cleaning Sewer Mains

National Water Main Cleaning Co.
50 Church St.
New York 7, New York
Cleaning Water Mains
Pipe, Cement Lining of

Neptune Meter Co.
19 W. 50th St.
New York 20, N. Y.
Meter Couplings, Yokes
Meter, Repair Parts,
Meters, Gas
Meters (Turbine Type)
Meter Testing Equipment
Meters, Water
Trap, Flame, Sediment, Steam, Drip.

Nichols Eng. & Research Corp.
70 Pine Street
New York 5, N. Y.
Driers, Sludge
Incinerators

Nooter Corp.
1410 S. 2nd St.
St. Louis 4, Mo.
Bins, Storage

O

Omega Machine Co.
Div. of B-I-F Industries Inc.
350 Harris Ave.
Providence, R. I.
Activated Silica Generators
Ammoniators
Chemical Feeding & Proportioning Equipment
Conveyors & Conveying Equipment
Dechlorinating Equipment & Chemicals
Electrical Control Equipment
Ferric Chloride
Water Treatment for Scale & Corrosion

The Oliver Corp.
400 W. Madison Street
Chicago 6, Ill.
Earth Moving Equipment
Trenching Equipment

Olin Mathieson Chemical Corp.
Indus. Chem. Div.
Mathieson Bldg.
Baltimore 3, Maryland
Acid Sulfuric and Hydrochloric
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Chlorinators
Chlorine, Liquid
Deodorizing
Hypo-Chlorinators
Soda Ash
Sodium Hypochlorite
Water Treatment for Scale and Corrosion
Well Cleaning Chemicals

P

Pacific Flush Tank Co.
4141 Ravenswood Ave.
Chicago 13, Ill.
Aeration Apparatus
Arresters, Flame
Diffusers-Plates, Tubes & Fittings
Digester Equipment
Distributors (Sewage Filter)
Gages (Liquid Level, Pressure Recording)
Gas Holders
Heaters, Digesters
Manometers
Siphons
Trickling Filter Equipment
Valves, Relief
Waste Gas Burners

Payne Dean & Co.
Clinton, Conn.
Gate Valve Operator

Peerless Pump Div.
Food Mchy. & Chem. Corp.
301 W. Ave. 26
Los Angeles 31, Calif.
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Deep Well
Pumps, Portable
Pumps, Self-Priming
Pumps, Sewage & Drainage
Pumps, Sludge
Pumps, Sump (and Cellar Drainer)
Pumps, Turbine

S. B. Penick & Co.
50 Church St.
New York 8, N. Y.
Fish Toxicants

Pennsalt Chemicals Corp.
3 Penn Center Plaza
Philadelphia 2, Pa.
Acid Sulfuric and Hydrochloric
Activated Alum
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Cements, Acid Proof and Alkali
Chlorine, Liquid
Coagulating Aids
Coatings, Acid and Alkali Proof
Ferric Chloride
Filter Alum
Insecticides
Paint (Acid Resisting)
Sodium Hypochlorite
Sodium Phosphates (Glassy)

Pennsalt Chem. Corp. Western
Div. of Pennsalt Chemicals Corp.
2901 Taylor Way
Tacoma, Washington
Acid Sulfuric and Hydrochloric
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Chlorine, Liquid
Ferric Chloride
Insecticides
Sodium Hypochlorite
Sodium Phosphates (Glassy)

Permutit Company
330 W. 42nd St.
New York, N. Y.
Aeration Apparatus
Activated Carbon
Boiler Feedwater & Equipment
Carbonators
Chemical Feeding & Proportioning Equipment
Combustion Indicators, Recorders
Dechlorinating Equipment & Chemicals
Deodorizing
De-Mineralization Equipment
Diatomite Filter Septums
Filter Underdrains, Water
Flocculating Equipment
Green Sand
Valves Motor Operated
Valves Special Automatic Including Remote Control
Water Softening Equipment
Water Treating Equipment for Scale & Corrosion
Zeolite
Zeolite Softeners

Phelps Dodge Refining Corp.
300 Park Ave.
New York, N. Y.
Taste and Odor Removal Chemicals

Phipps & Bird Co.
6th & Byrd Sts.
Richmond 5, Va.
Boiler Feedwater Treatment & Equipment
Buffer Solutions & Tablets
Comparators Color
De-Mineralization Equipment (Water)
Laboratory Apparatus Reagents & Equipment
pH Test Equipment
Photoelectric Colorimeters
Pumps, Vacuum
Residual Chlorine Test Apparatus
Samplers & Sampling Tables
Sewage Samplers
Sludge Samplers
Stirrers
Turbidimeters

Philadelphia Gear Works
G St. below Erie Ave.
Philadelphia 34, Pa.
Agitators
Gears, Speed Reducing
Valves, Hydraulic Cylinder Operated
Valves, Motor Operated
Variable Speed Transmissions

Philadelphia Quartz Co.
Public Ledger Bldg.
Independence Square
Philadelphia, Pa.
Coagulating Aids
Bituminous Coatings & Linings

Pittsburgh Coke & Chemical Co.
Grant Bldg.
Pittsburgh 19, Pa.
Activated Carbon
Bituminous Coatings & Linings
Coatings, Acid & Alkali proof
Corrosion Suppression
Waterproofing Paints, Compounds & Materials

Pittsburgh-Des Moines Steel Co.
3456 Neville Island
Pittsburgh, Pa.
Bins, Storage
Breechings Steel
Floating Covers
Gas Holders

Jos. G. Pollard Co.
New Hyde Park
Long Island, N. Y.
Jointing Compound & Materials
Pipe Tools
Valve Box Locators

Portland Cement Assn.
Dearborn & Grand Ave.
Chicago 10, Ill.
Concrete Pipe (Water & Sewage)

Henry Pratt Co.
2222 S. Halsted St.
Chicago 8, Ill.
Valves, Butterfly
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint

Preload Corp.
211 E. 37th St.
New York, N. Y.
Bins, Storage
Contractors, Water & Sewage

Prestite-Keystone Eng.
Products Co.
3738 Chouteau Ave.
St. Louis 10, Mo.
Bituminous Coatings & Linings
Cements, Sewer Pipe
Forms & Gaskets for Pipe Joints
Jointing Compound & Materials
Roof Coatings
Sewer Pipe Joints

Pressure Concrete Co.
1555 Helton St.
Florence, Alabama
Gunite Contracting

Price Bros. Co.
1150 E. Monument Ave.
Dayton, Ohio
Pipe, Concrete, Pressure
Pipe, Culvert
Pipe, Sewer
Saddles, Pipe
Siphons (Sewage Dosing)

Proportioneers, Inc.
Div. of B-I-F Industries Inc.
350 Harris Ave.
Providence, R. I.
Boiler Feedwater Treatment & Equipment
Calcium Hypochlorite
Chemical Feeding & Proportioning Equipment
Chlorinators
Dechlorinating Equipment & Chemicals
Diatomite Filter Septums
Ferric Chloride
Filter Equipment
Filter Media
Filters, Vacuum
Fluoridation Equipment
Laboratory Apparatus, Reagents & Equipment
Pumps, Diaphragm
Rust Prevention
Sewage Samplers
Water Softening Equipment
Water Treatment for Scale & Corrosion

R

Rensselaer Valve Co.
Troy, New York
Gates, Sluice
Hydrants (Fire)
Sleeves, Tapping (Valve)
Valves, Flap
Valves, Foot
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint
Valves, Motor Operated

Roberts Filter Mfg. Co.
640 Columbia Ave.
Darby, Pa.
Boiler Feedwater Treatment & Equipment
Filter Equipment
Filter Underdrains Water
Flocculating Equipment
Operating Tables (Filter)
Sludge Valves (Telescopic)
Valves, Mud and Plug
Water Softening Equipment
Zeolite & Zeolite Softeners

Rockwell Mfg. Co.
400 N. Lexington Ave.
Pittsburgh, Pa.
Lubricants, Valve
Meters, Water
Regulators, Pressure
Sludge Valves (Telescopic)
Valves, Cone
Valves, Four Way
Valves, Motor Operated
Valves, Mud & Plug
Valves, Hydraulic Cylinder Operated
Valves, Lubricated Plug
Valves, Mechanical Joint

W. S. Rockwell Co.
2763 Eliot Street
Fairfield, Conn.
Rubber Lined Pipes & Valves
Valves, Check
Valves, Float
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Motor Operated

Roots Connersville Blower Div.
900 W. Mount St.
Connersville, Ind.
Blowers, Air, Gas
Meters, Gas
Pumps, Centrifugal
Pumps, Self-Priming
Pumps, Vacuum

Royer Foundry & Mach. Co.
158 Pringle Street
Kingston, Pa.
Sludge Disintegrators

S

Safety Gas Main Stopper Co.
523 Atlantic Ave.
Brooklyn, N. Y.
Stoppers, Water Main

Schramm, Inc.
West Chester, Pa.
Compressors, Air
Concrete Breakers
Drilling & Boring Equipment

Simplex Valve & Meter Co.
7 E. Orange Street
Lancaster, Pa.
Controllers Flow, Level, Pressure, Temperature
Filter Equipment
Gages (Liquid Level, Pressure Recording)
Indicators, Large Dial Illuminated
Manometers
Meters, Electric
Operating Tables (Filter)
Orifices
Rate of Flow Controllers
Rate of Flow Recorders
Sand Expansion Indicators
Valves, Air Release & Vacuum Breaking
Venturi Tubes
Water Leak, Locating Instruments
Water Level Controllers
Water Level Recorders

M. B. Skinner Co.
3502 W. Sample St.
South Bend, Ind.
Clamps, Bell Joint
Clamps, Pipe Repair

A. P. Smith Mfg. Co.
East Orange, N. J.
Pipe Test Plugs
Sleeves, Tapping (Valve)
Valve Boxes
Valve Inserting Machines
Valves, Check
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint
Valves, Motor Operated

Smith & Loveless, Inc.
62nd & Merriam Drive
Merriam, Kansas
Alternators, Electric
Carbonators (Recarbonation)
Coatings, Acid & Alkali-Proof
Controllers, Flow, Level, Pressure, Temperature
Distributors (Sewage Filter)
Ejectors, Pneumatic or steam
Filter Equipment
Siphons (Sewage Dosing)
Tank Linings
Trickling Filter Equipment
Underground Pumping Stations
Water Level Control

Sparling Meter Company
225 N. Temple City Blvd.
El Monte, Calif.
Meters, Water (Consumer)
Meters, Water Compound

Speelmon Elevated Tank Service
822 N. Court Street
Rockford, Ill.
Tank Linings
Tank Maintenance & Repair

Spring Load Mfg. Co.
3610 First Ave. South
Seattle, Wash.
Pipe Cutting Machines
Pipe Tools (Asbestos, Cement)

Standard Dry Wall Products, Inc.
Box X
New Eagle, Pa.
Concrete Hardener
Pipe, Cement Lining of
Waterproofing Paints, Compounds, and Materials

Standard Steel Corp.
410 Solano Ave.
Los Angeles 58, Calif.
Drying Systems, Sludge

Stuart Corp.
516 N. Charles St.
Baltimore, Md.
Activated Carbon
Anthrafilt
Ash & Coal Handling Machinery
Conveyors & Conveying Equipment
Filter Equipment
Filter Media
Filter Underdrains, Water
Flocculating Equipment
Gates, Sluice
Grit Chamber Equipment & Grit Washers
Mixers & Mixing Equipment
Water Softening Equipment

Synchro Start Products, Inc.
8151 N. Ridgeway
Skokie, Ill.
Electrical Control Equipment
Engine Controls

T

Taller & Cooper
75 Front St.
Brooklyn, N. Y.
Chemical Feeding & Proportioning Equipment
Combustion Indicators & Recorders
Electrical Control Equipment
Gate Valve Operator
Laboratory Apparatus, Reagents & Equipment
Pumping Controls
Valves, Diaphragm
Valves, Motor Operated
Valves, Special, Automatic
Valves, Water Meter Special
Venturi Tubes
Water Level Controllers
Water Level Recorders

W. A. Taylor & Co.
7308 York Rd.
Baltimore 4, Maryland
Comparators Color
Laboratory Apparatus, Reagents & Equipment
pH Test Equipment
Photoelectric Colorimeters

Tennessee Corp.
619 Grant Bldg.
Atlanta, Ga.
Acid Sulfuric & Hydrochloric
Copper Sulfate
Dechlorinating Equipment & Chemicals
Ferric Sulphate
Fluoridation Chemicals
Thickeners (Sludge)

U

U. S. Electrical Motors, Inc.
200 E. Slauson Ave.
Los Angeles 54, Calif.
Gears, Speed Reducing
Motors, Electric
Speed Reducers, Transmission
Variable Speed Transmissions

U. S. Pipe & Foundry Co.
3300 First Ave. N.
Birmingham, Ala.
Fittings, Tees, Ells, etc.
Joints, Mechanical Flexible
Pipe & Fittings Lined
Pipe, Cast Iron
Pipe, Cement Lined
Pipe Joints (Mechanical)

U. S. Rubber Co.
1230 6th Ave.
New York, N. Y.
Acid, Sulphuric & Hydrochloric
Chemical, Conveying Equipment
Clamps & Sleeves, Pipe
Coatings, Acid & Alkali-Proof
Couplings, Flexible
Filter Aids
Forms & Gaskets for Pipe Joints
Hose, Air, Steam, Water, Suction
Insecticides
Joints, Expansion Pipe
Lubricants, Valve
Paint (Acid Resisting)
Pipe & Fittings Lined
Pipe & Tank Coatings
Pipe Joints (Mechanical)
Pipe, Plastic
Roof Coatings
Rubber Lined Pipes & Valves
Tank Linings
Tanks, Rubber Lined
Valves, (Rubber, plastic, glass or lead)
Waterproofing Paint, Compounds & Materials
Weed Killers
Well Cleaning Chemicals

V

Varsity Engineering Co.
207 South Ashley St.
Ann Arbor, Michigan
Screening Systems, Sewage

Vulcan Materials Co.
2019 Sixth Ave. N.
Birmingham, Ala.
Aggregates

W

W-K-M Mfg. Co., Inc.
ACF Valves Dept.
PO Box 2117
Houston, Texas
Valves, Check
Valves, Lubricated plug
Valves, Motor operated
Valves, mud and plug
Valves, Sludge (Telescopic)
Valves, Special Automatic

Walker Process Equipment Inc.
840 N. Russell Ave.
Aurora, Ill.
Aeration Apparatus
Anthrafilt
Carbonators
Clarifiers, Sewage & Water
Conveyors & Conveying Equipment
Diffusers, Plates, Tubes & Fittings
Distributors, Sewage
Filter Equipment
Filter Underdrains, Sewage
Filter Underdrains, Water
Floating Covers
Flocculating Equipment
Gas Diffusers
Gas Holders
Grinders, Garbage & Screenings
Grit Chamber Equipment and Grit Washers
Heaters Digester
Operating Tables (Filter)
Porous Tubes and Plates
Samplers & Sampling Tables
Screens, Sewage
Siphons, Sewage
Sludge Collectors
Sludge Samplers
Trickling Filter Equipment
Valves, Sludge
Valves, Special Automatic including Remote Control
Water Softening Equipment

Wallace & Tiernan Inc.
Box 178
Belleville, N. J.
Ammoniators
Activated Silica Generators
Boiler Feedwater Treatment & Equipment
Chemical Feeding & Proportioning Equipment
Chlorinators
Coagulating Aids
Dechlorinating Equipment & Chemicals
Deodorizing

Washington Aluminum Co.
Knecht Ave. & Penn R. R.
Baltimore, Maryland
Gates, Shear
Gratings, Flooring Treads, Railings

Water Seals, Inc.
9 S. Clinton St.
Chicago 6, Ill.
Waterstops

Weiman Pump Mfg. Co.
286 Spruce Street
Columbus, Ohio
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sewage & Drainage
Pumps, Sump (& cellar drainer)

Western Machinery Co.
650 5th Street
San Francisco 7, Calif.
Agitators
Mixers & Mixing Equipment
Pumps, Centrifugal
Pumps, Diaphragm
Pumps, Sewage & Drainage
Pumps, Sludge
Pumps, Sump (& cellar drainer)
Thickeners (Sludge)

Westinghouse Electric Corp.
Gateway Center, 401 Liberty Ave.
Pittsburgh 30, Pa.
Electrical Control Equipment
Fans Exhaust & Ventilating
Furnaces (Melting, Pouring, Ladles, Pots, etc.)
Gears, Speed Reducing
Generators (Electric)
Meters, Electric
Motors, Electric
Penstocks
Pipe, Plastic
Switchboard & Switch Gear
Transformers, Electric
Turbines, Steam
Valves, Butterfly
Valves, Gate
Valves, Motor Operated

West Virginia Pulp & Paper Co.
Industrial Chem. Sales Div.
230 Park Ave.
New York, New York
Activated Carbon
Deodorizing

White Motor Co.
White Diesel Engine Div.
1401 Sheridan
Springfield, Ohio
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines, Gas & Gasoline
Engines, Sludge, Gas

Wilkinson Products Co.
3987 Chevy Chase Drive
Pasadena 3, Calif.
Pipe Locators
Water Leak Locating Instruments

John Wiley & Son, Inc.
440 4th Ave.
New York 16, N. Y.
Books, Technical

R. D. Wood Co.
Public Ledger Bldg.
Philadelphia 5, Penna.
Fittings, Tees, Ells, Etc.
Hydrants (Fire)
Pipe, Cast Iron
Pipe, Cement Lined
Pipe, Culvert
Pipe Joints (Mechanical)
Valve Boxes
Valves, Gate
Valves, Mechanical Joint

Woodward Iron Co.
Woodward, Alabama
Pipe, Cast Iron

Worthington Corp.
Harrison & Worthington Aves.
Harrison, N. J.
Agitators
Comminuting Devices
Compressors, Air
Concrete Breakers
Concrete Mixer
Condensers (Steam)
Drilling & Boring Equipment
Drives, V-Belt
Ejectors, Pneumatic or Steam
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines (Gas & Gasoline)
Engines, Sludge, Gas
Gears, Speed Reducing
Generators (Electric)
Mixers & Mixing Equipment
Motors, Electric
Nozzles, Spray (Water & Sewage)
Orifices
Pumps, Acid-Handling
Pumps, Centrifugal
Pumps, Deep Well
Pumps, Hydraulic (Pressure Boosting)
Pumps, Portable
Pumps, Self-Priming
Pumps, Sewage & Drainage
Pumps, Sludge
Pumps, Sump (And Cellar Drainer)
Pumps, Turbine
Pumps, Vacuum
Switchboard & Switch Gear
Tools, Pneumatic
Turbines, Steam
Valves, Butterfly
Valves, Gate
Variable Speed Transmissions

Worthington Gamon Meter Div.
Worthington Corp.
296 South Street
Newark 5, N. J.
Meters, Water (Consumer)

Y

Yeomans Bros. Co.
1999 N. Ruby St.
Melrose Park, Ill.
Aeration Apparatus
Clarifiers, Sewage & Water
Compressors, Air
Digester Equipment
Distributors, Sewage Filter
Ejectors, Pneumatic or Steam
Nozzles, Spray, Water & Sewage
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sludge
Pumps, Sewage & Drainage
Pumps, Vacuum
Pumps, Sump and Cellar Drainer
Trickling Filter Equipment

Z

Zimmer & Francescon
Moline, Illinois
Pumping Stations, Sewage

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